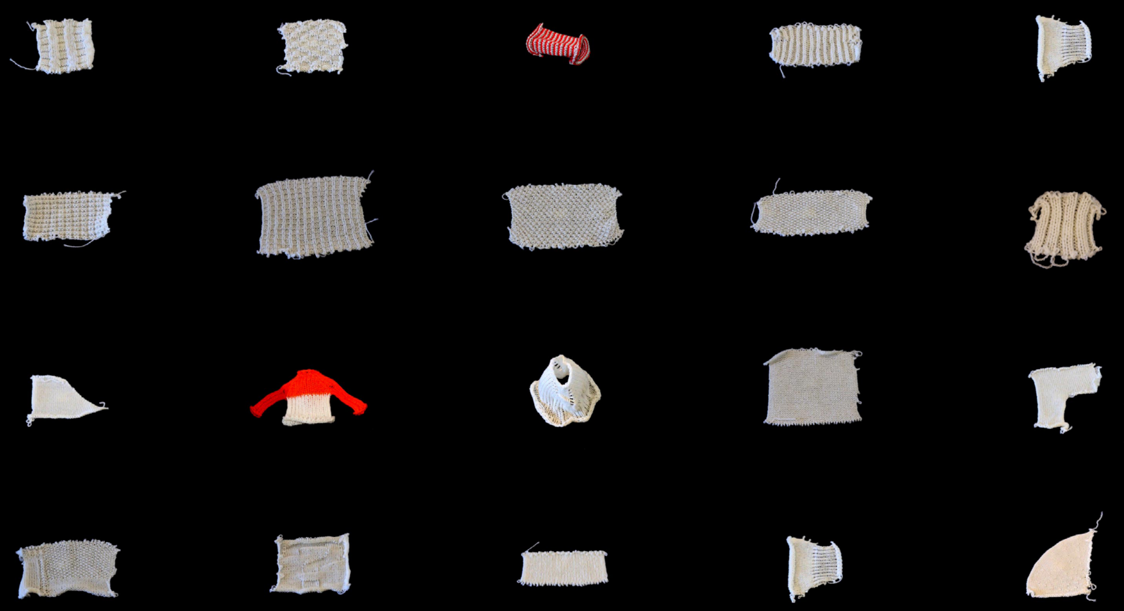
# HACK 1 KNIT 2

//making whole-garment knitting more open

Jess Peter



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**This report was submitted for partial fulfillment of the Oslo School of Architecture and Design requirements for Master of Design (May 2019).**

# Acknowledgements

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I extend many thanks to the Oslo Academy of the Arts, and, in particular, Dagfinn Skoglund, for allowing me to use their knitting facilities.

Thanks to Camilla Bruerberg and my other interview participants for sharing their knowledge and for their patience.

Thank you to Jim McCann and the Carnegie Mellon Textiles Lab for developing Knitout and for taking the time to respond to my emails.

# A Note on Imagery

This report was completed as a requirement for a Master's of Design diploma. Certain sections are also intended to provide usable information to people interested in whole-garment knitting. As such, numerous images are used throughout the report to illustrate ideas and clarify concepts. These images are cited within their captions, and are complete and accurate to the best of my knowledge.

Images from knitting magazines and guides that are used to introduce each section and subsection are not cited in place. Sources for these images are listed below.

## Section Image Sources

### Introduction:

Photo of gloves and socks, *Mon Tricot: Knit & Crochet*: no. 19 (1974): 43, https://archive.org/details/mon-tricot-md-19.

### Digital Machine Knitting:

Cover illustration, *Hutchinson's Knitted comforts for the Forces: Simple Up-To-Date Patterns for the Navy, Army & Air Force* (194?), https://archive.org/details/krl00536816/page/n23.

### State of the Art:

Cover photo, *Knit Menagerie*: no. 1 (1987), https://archive.org/details/Patons_495_Knit_Menagerie_vol._1/page/n3.

### Schedule:

Back cover photo, "Family Cardigans", *Patons*: no. 657 (n.d.), https://archive.org/details/Patons_657_Family_Cardigans/page/n23.

### Needs Assessment:

Back cover photo, *Patons Knitting Book*: no. 388 (n.d.), https://archive.org/details/Patons_388_Vintage_Toddler_Knits/page/n19.

### Process:

Photo of woman and child holding hands, *Mon Tricot: Knit & Crochet*: no. 19 (1974): 1, https://archive.org/details/mon-tricot-md-19.

### Experiments:

Cover photo, "Best in Vests," *Spinnerin*: no. 197 (n.d.), https://archive.org/details/spinnerin-best-in-vests.

### Key Principles of Whole-garment Knitting:

Back cover photo, "Beehive Hand Knits," *Fashion Book*: no. 144 (n.d.), https://archive.org/details/Patons_144_Women_s_Fashions/page/n3.

### Sample Objects:

Cover photo, "Hospital Set," *Bestway*: no. 110. (194?), https://archive.org/details/krl00536811.

### Future Implications:

Photo illustrating "Arizona Shadows" sweater pattern, *Knitter's*: no. 21 (1990), https://archive.org/details/Knitters_21_1990-11.

### Conclusions:

Photo and instructions for "plain or camaïeu..." cardigan, *Mon Tricot: Knit & Crochet*: no. 19 (1974): 28, https://archive.org/details/mon-tricot-md-19.

### Appendices:

Photo and instructions for "specially for beginners" socks, *Mon Tricot: Knit & Crochet*: no. 19 (1974): 53, https://archive.org/details/mon-tricot-md-19.

### Glossary:

Back cover photo, "Knits for Men of Action", *Patons*: no. 766 (n.d.), https://archive.org/details/Patons_766_Knits_for_Men_of_Action.

### Bibliography:

Spread featuring numerous knitting magazines, *Mon Tricot: Knit & Crochet*: no. 19 (1974): 89, https://archive.org/details/mon-tricot-md-19.

## Subsection Images Source

*Patons Knitting Book*: no. 388 (n.d.), https://archive.org/details/Patons_388_Vintage_Toddler_Knits/page/n19.

# Contents

# Abstract

This project examines how open-source technology could enable more designers to incorporate whole-garment knitting into their practice by allowing them to bypass the restrictively licensed and unintuitive software developed by knitting machine manufacturers.

This approach stands as a contrast to research completed by other scholars that acknowledges the inhibitory nature of whole-garment knitting technology, but accepts it as a given. These papers often place the burden on the software users to find ways to negotiate its limitations through alternative company structures or increased training.

My work instead proposes the need for an alternative to current software solutions offered by knitting machine manufacturers. This alternative should be based in principles that value openness and community. In this vein, I have undertaken a period of practice-based research to create knitted samples using the open-source file specification Knitout in conjunction with a Shima Seiki whole-garment knitting machine. Knitout is not officially supported by Shima Seiki.

These samples demonstrate that it is possible for a user to design whole-garment knitted objects without the use of Shima Seiki's (or other knitting machine companies') software. The documentation of this project, both online and in this report, also provides resources for others who wish to contribute to the development of alternative, more open methods of designing for whole-garment knitting.

This project also explores applications for whole-garment knitting that could be possible if knitting machine manufacturers provided support for open-source methods of working with their hardware.

Section 1.

# //Introduction

# Introduction

## //On Knitting

In knitting, a series of knots are tied along a piece of yarn to make fabric. It feels simultaneously obvious and incredible that such an old-fashioned practice remains in use in both industrial and leisurely applications.

While some knitters prefer to work with yarn in more traditional ways, with needles or hand-powered machines, others embrace new technology, adopting new gadgets into their craft, picking up ideas and dropping stitches. This project is for the latter group.

1 Knitout is an open-source file format for designing knit garments created by The Carnegie Mellon Textiles Lab, discussed in section **State of the Art: Open-source Technology**.

## //Goals

Throughout this project, I will experiment with using the Knitout file specification[1] to generate knitted forms with industrial-grade Shima Seiki whole-garment knitting machines through code.

By sharing my findings and the objects I make, I aim to:

1. Lessen the learning gap to others interested in exploring whole-garment technology
2. Make a case for how whole-garment technology could be incorporated into more makers' practices

My approach is intended as a quiet opposition to the control exerted by many modern knitting machine manufacturers over users. Shima Seiki's, for example, software suite is both prohibitively expensive and challenging to use outside of a few pre-set forms. By contrast, my work will emphasize openness: openness of learning, openness of use, and, openness towards creativity.

In addition to the objects I made and my documentation online (discussed in greater detail in **Experiments**), this book itself was created with the intent of contributing to the fulfillment of my first objective. Sections such as **Process** and **Principles of Whole-garment Knitting**, in addition to various appendices, are included with the intent to educate curious makers looking to work with whole-garment knitting, who have come across this report in AHO's library or on the internet.

## //My Contribution

The transformative role of technology in knitting has been explored in myriad ways across disciplines. However, the specific technology used and my approach renders many aspects of my research unique.

Many makers have explored open-source ways of working with commercial-grade knitting machines, such as All Yarns Are Beautiful and Electro-knit (see **State of the Art: Open-source Technology** and **State of the Art: Artists**). I have chosen to work with Shima Seiki industrial grade knitting machines because, with the added complexity of these machines, there are also added possibilities. Most projects or "hacks" working with commercial-grade knitting machines only offer users the ability to change colours and the height of the knitted fabric. With Knitout and whole-garment knitting, the user can vary the type of each stitch in a row, altering not only the colours of the fabric, but the structure as well.

My work is based on the Knitout file specification, and builds upon the work of members of the Carnegie Mellon Textiles Lab. I would like to build on the Knitout documentation, which is sparse in many places. My work also diverges from theirs as my motivations are more based in design research than computer science. The knitting techniques I explored I chose based on how well they might apply to different design fields, and how well they might be built upon and combined.

Finally, I would like to acknowledge the work of Jane Taylor, Jenny Underwood, and others who have investigated challenges related to working with whole-garment knitting equipment, which, in many cases, includes issues related to access and learnability. In her work, Underwood included a lexicon of how to create shapes in the official Shima Seiki software,[2] which I used as a reference in this project. Though their work influenced this project greatly, I have chosen to investigate ways of using industrial grade machine knitting in a manner that bypasses officially supported software solutions. By necessity, this implies a different approach than their work.

2 Jenny Underwood, "The design of 3D shape knitted preforms," (PhD diss., RMIT, 2009), 62–137.

## //Scope

Working with Knitout and Shima Seiki knitting machines is not well understood, particularly from a design-centric approach. With this in mind, as well as the brevity of the semester, my work consists of predominantly practice-based research.

Throughout this project I have struggled with the role of visual interfaces in designing my project. I have ultimately opted to not include mock-ups or other prototypes of visual interfaces. It could be well argued that working purely with code when graphical user interfaces are much more common in many designers' workflows runs contrary to my goal of increasing the accessibility of the technology. However, understanding the abilities and limitations of the technology must precede the development of graphical software, leaving insufficient time to develop a well-reasoned mock-up for a design interface. I would also emphasize that accessibility is not always the same thing as ease of use. Certainly, a visual interface would be a fruitful next step for someone exploring this area. With my project, though, I've aimed to thoroughly and publicly document my process, so that the user can, with work, understand the role of each knitting operation, so they may better learn not just *what* works but *why*.

Another significant factor restricting use of experimental whole-garment knitting among designers outside of the mass-market fashion industry is the cost and physical accessibility of the machines. Though I discuss this aspect of the technology occasionally throughout my work, this project is predominantly concerned with the inaccessibility of the current software system, and does not address the finances involved in purchasing a machine.


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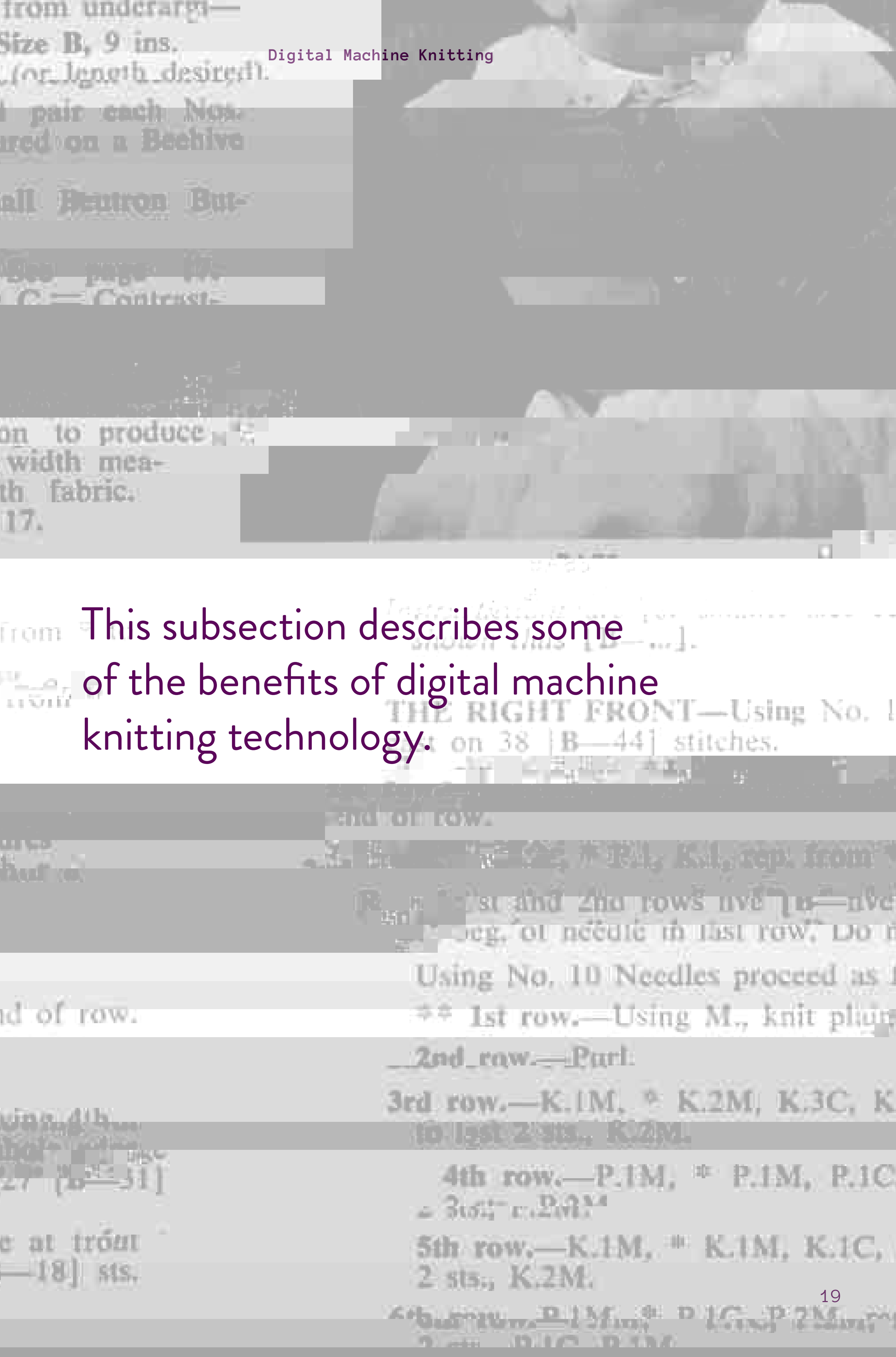
Section 2.

# //Digital Ma-chine Knitting

# //Digital Machine Knitting: Opportunities



This subsection describes some of the benefits of digital machine knitting technology.

# Opportunities in Digital Machine Knitting

Knitting has played a significant role in world—and particularly Norwegian—culture for hundreds of years.[1] Even today, knitting plays a big part of many people's daily life: from local knitting circles, where community members gather to socialize and pick away at personal projects, to local artisans whose stitches earn them a living, to knitwear's impact on the billion dollar global fashion industry—which impacts almost everyone directly and indirectly.

Though the fundamentals of knitting haven't changed, digital knitting technologies developed in the past few decades offer new ways for professionals and hobbyists to explore the craft.

1 Ingun Grimstad Klepp. "Knitting." Store norske leksikon, last updated December 11, 2018. https://snl.no/strikking.

2 Billy Hunter, "Max Mara: A champion of Shima Seiki WHOLEGARMENT technology," published November 6, 2015. https://www.knittingindustry.com/max-mara-a-champion-of-shima-seiki-wholegarment-technology.

## //Time

It takes significantly less time to create a garment using a digital knitting machine than by hand or with an analogue machine. For instance, a sweater that might take days to knit by hand would only take minutes to an hour or two from a whole-garment knitting machine.

A shorter production time would lower the labour cost of manufacturing for designers wishing to sell their wares. Hobbyists might take advantage of faster production as an opportunity to iterate more on designs, rather than having to commit to a given knit pattern for hours or days as they complete it.

## //Unique Capabilities

Various programs enable makers to convert photographs and illustrations to knitted fabrics, which would require laborious planning with non-digitized knitting. More unique capabilities are enabled by whole-garment knitting. Whole-garment knitting machines, initially devised by Shima Seiki, are able to produce complete, seamless garments that often do not need additional assembly.[2] Figure 2.1 shows a sample of garment types possible to create with whole-garment knitting.

Outside of programs created by knitting machine manufacturers and software companies, designers, artists, and other makers have developed other, less orthodox ways of incorporating knitting into their craft (see **State of the Art: Open-source Technology** and **State of the Art: Artists**), and in doing so, tested the limits of what knitting is capable of.

## //New Ways of Making

Though digital knitting machines may draw inspiration from hand knitting, operating them is fundamentally different. Often, they are programmed through visual interfaces on a computer. Though in the next section I discuss some of the limitations created by one commonly used software suite, it is important to highlight that these issues are not inherent to the process of digitization itself, but rather from the complexity, limited resources, and work culture associated with these particular software programs.

Writing on the implications of digital practices on craft, Mike Press writes, “now craft is beginning to explore creative strategies and approaches that open up new possibilities of form, meaning, and significance in our digital culture.”[3]

When reflecting on this quote, we can imagine how technology like whole-garment systems could enable makers to create knitted forms that are aesthetically unique to other knitted goods.

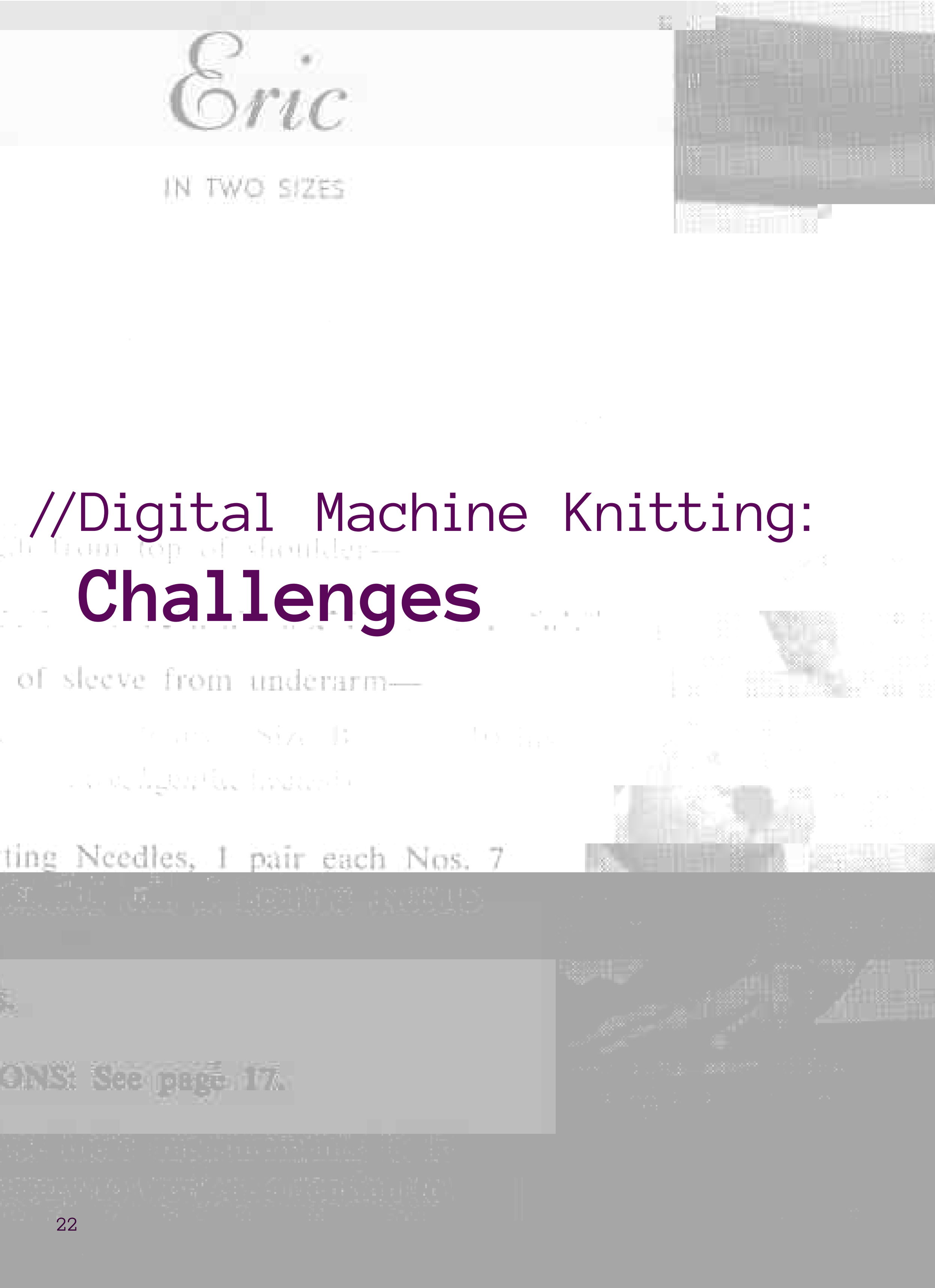
Far from just broadening the visual forms producable from knitting, digitized machines may also encourage more people to take up the craft: The ability to make through digital interfaces or code implies a different skillset than manual knitting methods. Other knitters, such as designer/researcher Jane Taylor, may ultimately find that their preferred way to work with digitized knitting technology is to combine it with hand knitting, or other methods of creation.[4]

3 Mike Press, “Handmade Futures: The emerging role of craft knowledge in our digital culture,” NeoCraft: Modernity and the Crafts (2007): 249.

4 Jane Taylor and Katherine Townsend, “Reprogramming the hand: Bridging the craft skills gap in 3D/digital fashion knitwear design,” Craft Research 5, no. 2 (2014): 170.

**Figure 2.1. Photo of models wearing clothing created all or in part with whole-garment technology at Shima Seiki’s 2016 fashion show.**

(Fashion designs by Kay Chan Hau Kei for Shima Seiki, photo published February 10, 2017. http://www.shimaseiki.com.hk/events/ks16_e.html.)




# //Digital Machine Knitting: **Challenges**

This subsection details some of the restrictive qualities of digital machine knitting hardware and software.

# Challenges in Digital Machine Knitting

Early in this report, I identified that I chose to focus on industrial-grade knitting machines, given their unique capabilities, and the relatively sparse amount of information on using them outside of the official software systems. This lack of information may be intentional on the part of the manufacturers as it forces consumers to be a part of what have become somewhat exclusive ecosystems.

For the purposes of this paper, I am focusing on Shima Seiki knitting machines, as that is what I have access to. Shima Seiki is one of the leading manufacturers of industrial grade knitting machines and the industry leader in whole-garment knitting technology.[5] Jane Taylor's interviews with designers and technicians working with whole-garment knitting indicate that Shima Seiki's main competitor, Stoll, shares many of the issues discussed below.[6]

## //Cost and Physical Access

Cost may be a significant barrier to makers wanting to use a Shima Seiki knitting machine. Though the company doesn't publicly publish the prices of their machines online, a magazine article from 2017 placed the cost of a whole-garment machine at almost 160,000 USD.[7] Additionally, many technicians are encouraged to take training courses in Japan in order to learn the technology, adding to the cost of learning.[8]

Educational institutions may be one of the few means by which users outside of the mass-market manufacturing industry can directly use this technology. Universities such as Parsons,[9] RMIT University Australia,[10] the Aukland University of Technology,[11] and the Oslo Academy of the Arts (or "KHiO" for short, from the Norwegian), do own industrial-grade knitting machines. However, access to the machines is often restricted given the cost of these machines and the skills needed to operate them.[12]

Even in institutions with the knitting machine hardware, the available software adds additional barriers. With Shima Seiki's SDS-ONE APEX3 software suite, for example, the technology is generally licensed at significant cost to a single computer.[13] This means that only one user at a time can develop her designs which is a time-consuming process. An interview with one technician in Taylor's work suggests that Stoll's licensing might be somewhat more flexible as to allows the software to run on different machines.[14]

5 Kazunori Takada and Emi Urabe, "These Hi-Tech Knitting Machines Will Soon Be Making Car Parts," published October 2, 2017. https://www.bloomberg.com/news/articles/2017-10-01/heir-to-1-9-billion-knitting-empire-is-taking-it-into-car-parts.

6 Jane Taylor, "The technical designer: a new craft approach for creating seamless knitwear," (PhD diss., Nottingham Trent University, 2015).

7 Kazunori Takada and Emi Urabe, "These Hi-Tech Knitting Machines."

8 Ibid, 39, 85.

9 "L2 Knit Lab," The New School Parsons, accessed October 29, 2018. http://resources.parsons.edu/labs/l2-knit-lab.

10 "Course Title: Perform knitting operations," RMIT University, accessed October 29, 2018. http://www1.rmit.edu.au/courses/c5210manu7212c1005.

11 "AUT Textile Design Lab," the Auckland University of Technology, accessed October 29, 2018. https://tdl.aut.ac.nz.

12 Taylor, 99.

13 Ibid, xix, lii.

14 Ibid, xix.

# //Lack of Learning Resources

Though the SDS-ONE APEX3 software system does have multiple PDF help guides, I found it difficult to search, and difficult to determine which guide I should consult for different types of help (see figure 2.2). These guides feature steps that walk the user through basic features of the program, and complicated descriptions of different functions available in the program. I found there was a large disconnect between the step-by-step instructions and the complex function descriptions. Translation issues, jargon, and difficult-to-search for errors further diminish the use of the guides (see figure 2.3).

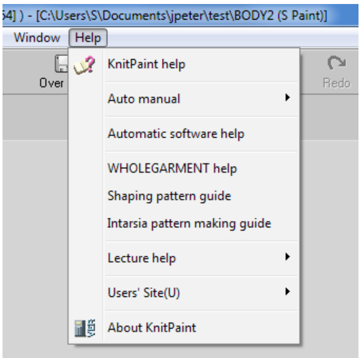



**Figure 2.2. Users may have difficulty determining which help resource to consult.**

(Shima Seiki, Screenshot of KnitPaint, accessed May 3, 2019.)

In terms of support, it seems that Shima Seiki relies on courses for technicians, rather than providing materials so users can teach themselves skills. Indeed, many of the designers and technicians interviewed by Taylor attended formal training.[15]

15 Ibid, lxxv – xcix.

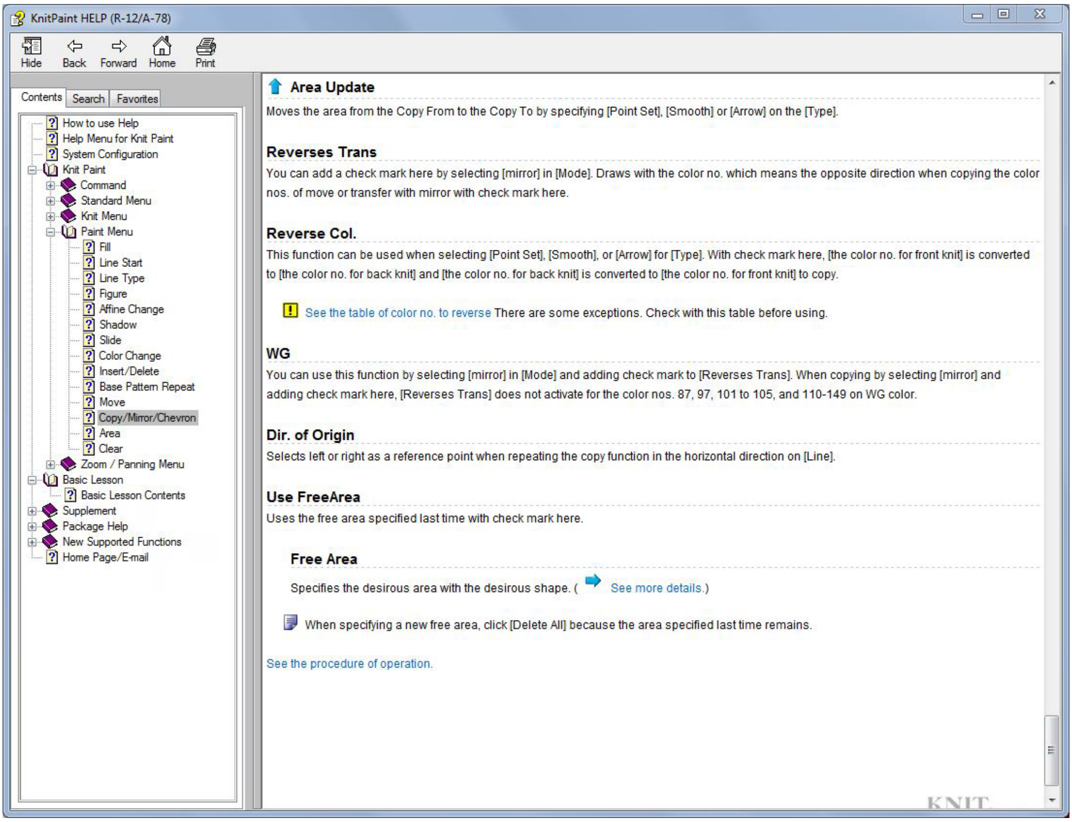



**Figure 2.3. A screenshot of the Shima Seiki user manual that demonstrates the organization of content and technical language used.**

(Shima Seiki, Screenshot of KnitPaint Help on topic Copy/Mirror/Chevron, accessed May 3, 2019.)

It's possible that the lack of resources is to protect the company's intellectual property, and to sustain the part of their business related to providing on-site training. Though it's difficult to confirm this, the company is known to take its intellectual property seriously: Shima Seiki has filed over 2,000 patent applications for developments related to its whole-garment technology,[16] and they successfully requested the Carnegie Mellon Textiles Lab to make some research on their equipment private.[17, 18]

16 Shima Seiki, "About WHOLEGARMENT," accessed February 12, 2019, http://www.shima-seiki.com/wholegarment.

17 "DAT-format" (Github code repository), last updated May 16, 2018. https://github.com/textiles-lab/DAT-format.

## //Technical Complexity of Software

The KnitPaint program is in many ways the core of the SDS-ONE APEX3 software suite. I discuss this software again in **State of the Art: Commercial Solutions**. It is here that users can create a pattern compatible with the machines, either from scratch or from an existing template.

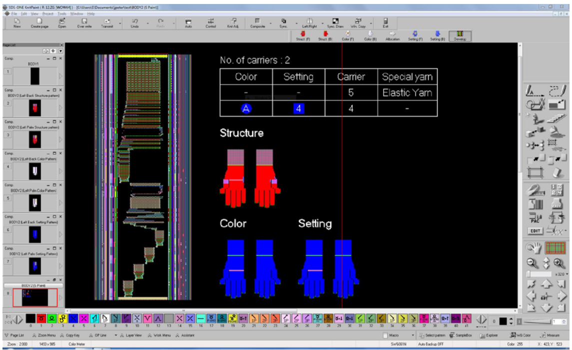



**Figure 2.4. A glove in the KnitPaint program.**

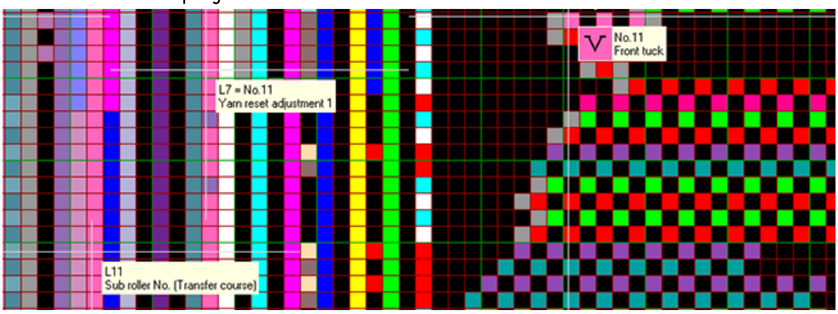
(Shima Seiki, Screenshot of KnitPaint, accessed May 3, 2019.)

In this program, users draw on a gridded screen (see figure 2.4). Though straightforward in theory, each colour a user can draw with represents one of more than 200 potential knitting operations. Users must know how to use these colours, understand their limitations, and be able to work through seemingly uninterpretable errors as they arise.

Furthermore, a given colour command may function differently when used in different parts of a program (figures 2.5).

Unlike punch card knitting machines, where punch cards might strongly resemble the output pattern, digital knitting patterns, and, in particular, whole-garment patterns, can look dramatically distorted compared to the knit output. This can make it difficult for users just learning the technology to actualize a project.

18 I asked Jim McCann about this over email. In an email dated April 29, 2019, McCann stated that Shima asked them to take the files down, and the Carnegie Mellon Textiles Lab obliged. He maintains that the relationship between Shima Seiki and Carnegie Mellon is positive. My criticism of Shima Seiki's intellectual property enforcement is my own and does not reflect the beliefs of the Carnegie Mellon Textiles Lab.




**Figures 2.5. The pink square representing command no. 11 (like other commands) means different things depending on where in the pattern it is used.**

(Shima Seiki, Screenshot of KnitPaint, accessed May 3, 2019.)

## //Software Wizards as Barriers to Creativity

Possibly in response to the difficulty of using KnitPaint, the SDS-ONE APEX-3 features a number of predesigned patterns users can choose from as a starting point for their design. These include hats, gloves, and sweaters, but vary based on the machine and software version used. With the Shima Seiki Automatic Wizard, "the user is guided through the steps to create a programme, a process that only requires a basic knowledge and understanding of the underlying system and its possibilities."[19]

Though these wizards may lower the barrier to entry for working with the system, the relatively limited customization possible with the wizard ultimately restricts the amount of creativity and control the designer has over the output. **Appendix A** includes screenshots of most of the options offered to designers when using the software creation wizard to design a pair of gloves. Discussing the increasing popularity of wizard-based design among knitwear designers and technicians, Sayer, Wilson, and Challis write:

> Do we really want our clothing to be designed by machine manufacturers? If so, then designing 3D seamless garments could become nothing more than a process of mix and match with predefined garment modules (type of neckline, sleeve shape, etc.). Could this even be called design?[20]

## //The Communication Bottleneck

Eckert,[21] Underwood[22] and Taylor[23] all discuss communication difficulties between knitwear designers and knitting machine technicians. Eckert refers to this as "The Communication Bottleneck" (illustrated on the following page in figure 2.6).[24] Commercial pressures to produce efficiently,[25] company structure,[26] and lack of a shared language[27] are pointed to as partial causes of this phenomenon. As a result there is little skill sharing. Taylor summarizes that, "with experience [working with knitting machine technicians], designers tend to learn about the restrictions of the technology rather than the possibilities. They are told what it cannot do, not what it can do, and crucially, not how it does it."[28]

Even users outside of the mass-market fashion industry may be affected by these rigidly defined "designer" and "technician" roles. Smith, reporting on a weeklong training course for designers at Shima Seiki headquarters in Japan, was never taught KnitPaint—an essential tool to determine the shaping of a

19 Taylor, "The Technical Designer," 34.

20 Kate Sayer, Jacquie Wilson, and Simon Challis. "Seamless knitwear–The design skills gap." The Design Journal 9, no. 2 (2006): 44.

21 Claudia Eckert, "Managing effective communication in knitwear design," The Design Journal 2, no. 3 (1999): 29–42.

22 Underwood, "The design of 3D," 23.

23 Taylor, "The Technical Designer."

24 Eckert, "Managing effective communication," 34.

25 Taylor, "The Technical Designer," 34.

26 Ibid, 79.

27 Ibid, 10 and 73.

28 Ibid, 94.

garment—and only received a day's training on whole-garment technology.[29] Taylor similarly reports that designers she interviewed had only been offered formal training sessions in CAD systems and not KnitPaint.[30]

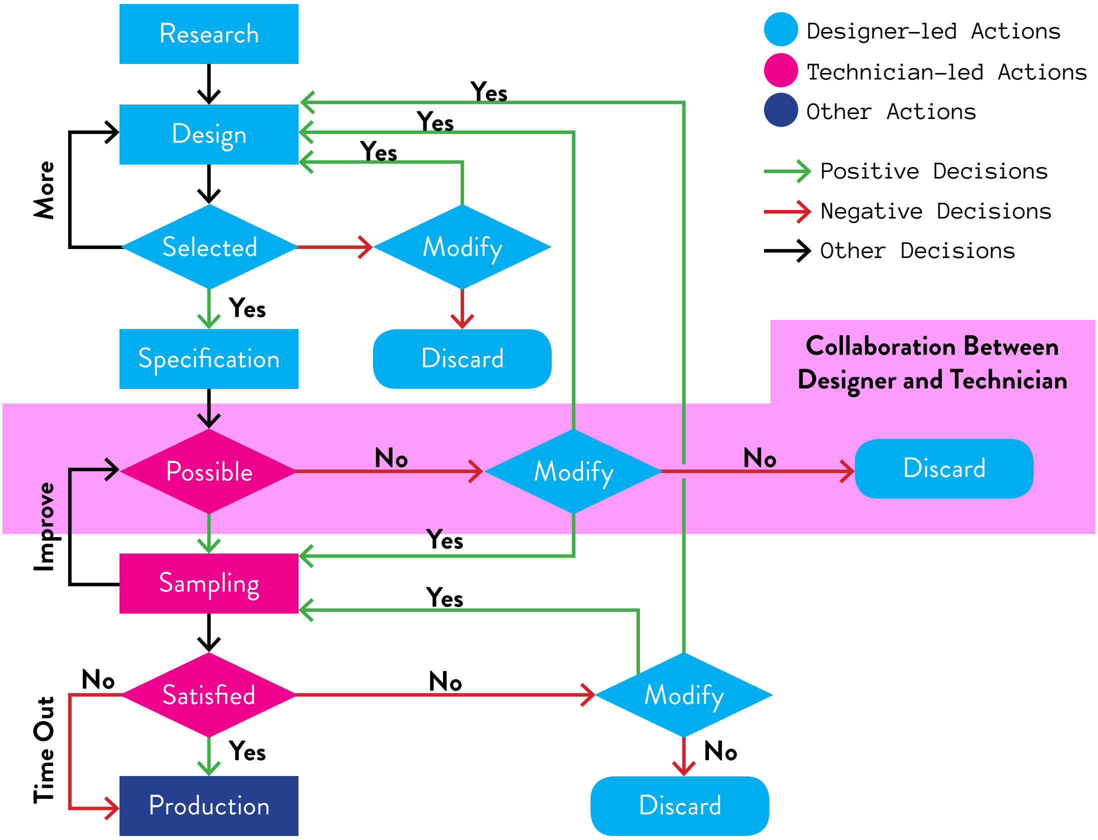



**Figure 2.6. A diagram by Claudia Eckert demonstrating the limited communication between designers and technicians, redrawn by me.**

(Original diagram by Claudia Eckert, "The Communication Bottleneck," "Managing effective communication in knitwear design," The Design Journal 2, no. 3 (1999): 32.)

## //Proposed Solutions

The researchers referenced in this section came up with different suggestions as to how some or all of these challenges could be mitigated. Many of their solutions relate to a change in training procedures or a change in the policies of the companies that employ designers.

Taylor proposes that challenges related to whole-garment knitting are best tackled by a change in how machine knitting is taught,[31] and a change in the structure of design teams. More specifically, a technician and a designer would work together throughout the design process.[32] This would be sup-

29 Smith, 101.

30 Taylor, "The Technical Designer," 85.

31 Ibid., 226.

ported by more cross-training and an emphasis on teaching creative teams to discuss tasks in a shared language.[33]

Underwood sees her Shape Lexicon–a compendium of instructions for how to create different shapes in KnitPaint–as a potential resources for designers to better understand the creation, possibilities and limitations of whole-garment knitting when working in creative teams.[34]

Eckert proposes multiple changes to companies' organizational structures to address communication issues between designers and technicians. She suggests the implementation of software that converts design specifications into less ambiguous terms before being shared with technicians, cross-training between designers and technicians, and employing managers with both technical and fashion backgrounds, amoung other suggestions, as solutions.[35]

Sayer et al. suggest that it would be beneficial for post-secondary institutions to teach knitwear students whole-garment knitting techniques, to make them more appealing to companies following graduation.[36]

While I acknowledge that these researchers are working in different fields, I find it notable that while all acknowledged that the software was difficult to use and challenging to problem-solve, all accept these issues as givens.

32 Ibid., 232.

33 Ibid., 226.

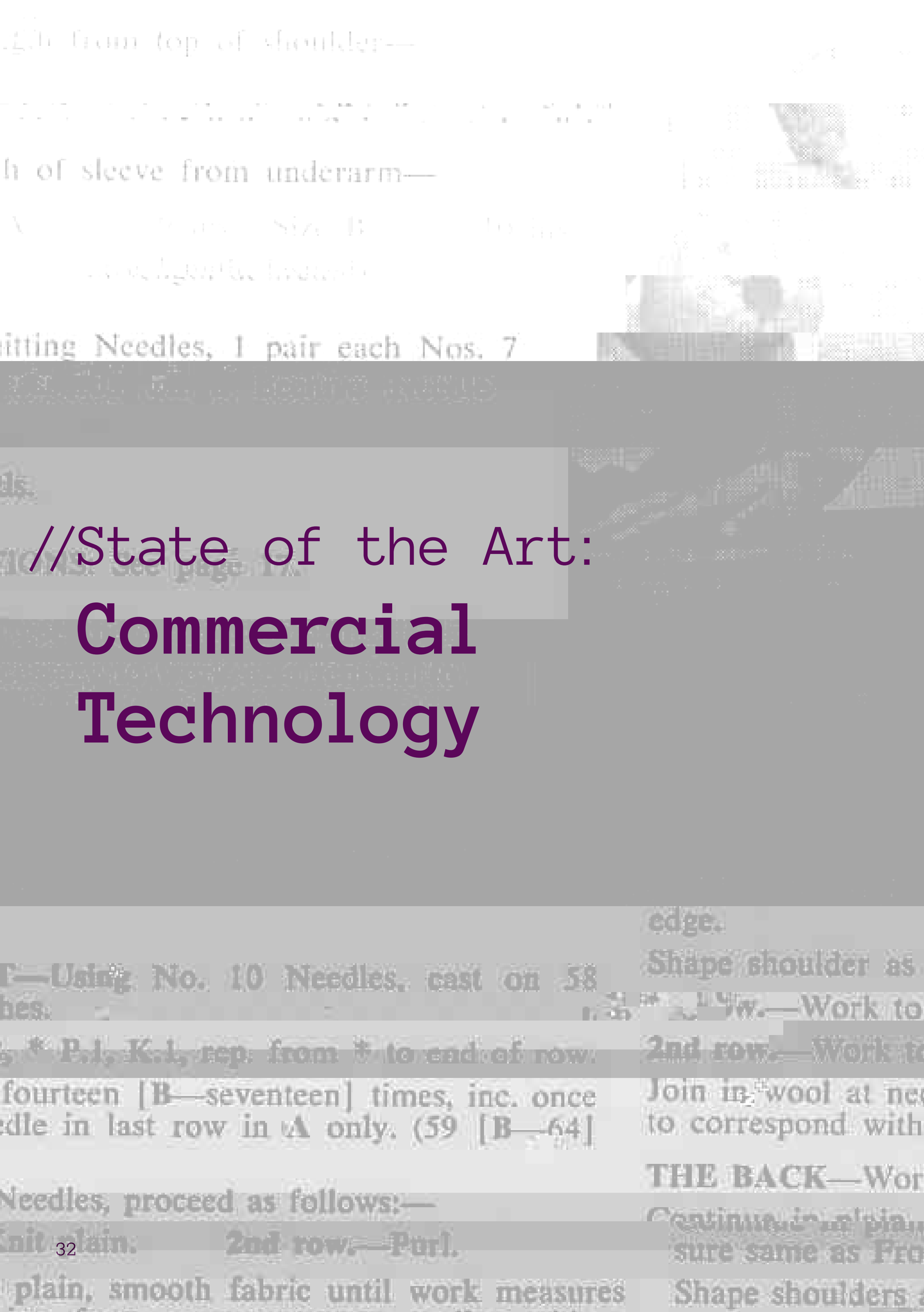
34 Underwood, "The design of 3D," 163.

35 Eckert, 41.

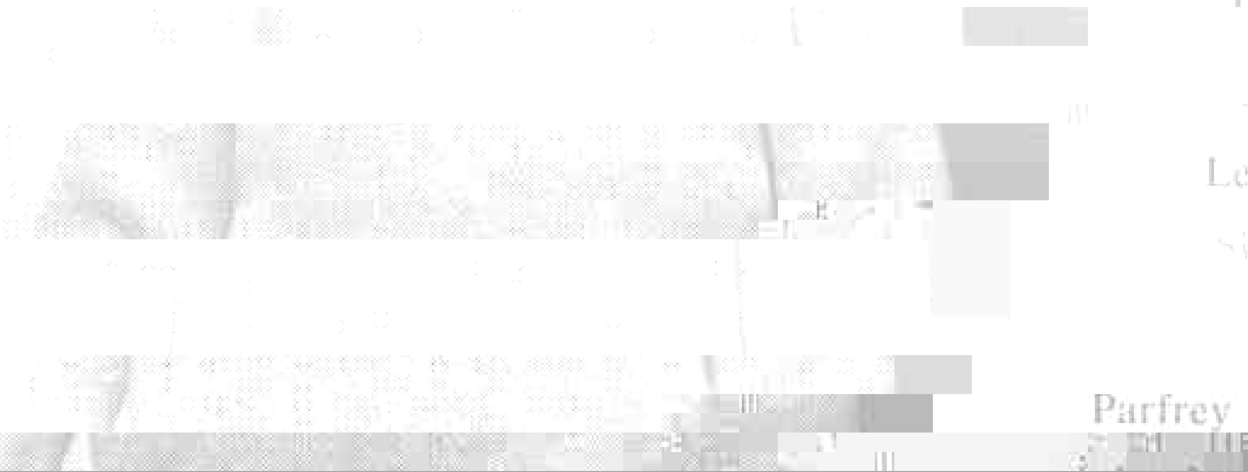
36 Sayer, Wilson, and Challis, 49.

Section 3.

# //State of the Art




# //State of the Art: **Commercial Technology**



This subsection describes some notable companies that produce knitting hardware and software in a traditional close-sourced model.

# Commercial Technology

## //SDS-ONE APEX3

The SDS-ONE APEX3 is the name of Shima Seiki's software bundle.[1] The company is very protective of their software, and it is challenging to locate detailed information on all supported features. That said, modern releases of their software feature utilities like a pattern-editing and a simulation program.[2] There is also a program for using image files to create a colourful design on the output garment.[3, 4]

The program that I observed as being most used by KHiO staff (and, evidently, most knitting machine technicians, as discussed in **Digital Machine Knitting: Challenges**) is called KnitPaint. This software acts as a sort of visual coding interface where users draw using different colours to represent different machine instructions, as described in the previous section.

## //DesignaKnit 8

DesignaKnit 8 is a software suite that can work on more affordable, consumer-grade knitting machines.[5, 6] It features a pattern drafting tool, an image-to-colour pattern conversion tool called Graphics Studio (fig 3.1), and a program called Stitch Designer (fig 3.2), which allows the user to design a knitted piece by selecting different stitch types.[7] Since this software is geared towards consumer-grade knitting machines, it does not have tools capable of designing for whole-garment knitting machines.

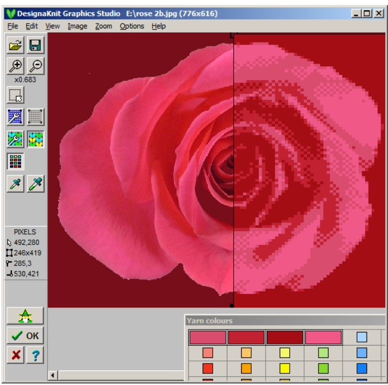



**Figure 3.1. Screenshot of DesignaKnit 8's Graphics Studio.**

(Soft Byte Ltd., Screenshot of Graphics Studio software, accessed May 3, 2019. https://www.softbyte.co.uk/designaknit.htm.)

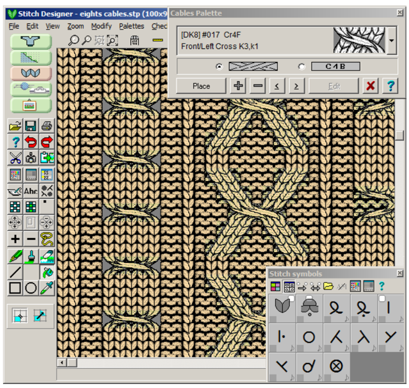



**Figure 3.2. Screenshot of DesignaKnit 8's Stitch Designer.**

(Soft Byte Ltd., Screenshot of Stich Designer software, accessed May 3, 2019. https://www.softbyte.co.uk/designaknit.htm.)

1 Shima Seiki, "SDS-ONE APEX3 Flat Knitting," accessed October 29, 2018. http://www.shimaseiki.com/product/design/sdsone_apex/flat.

2 Ibid.

3 Ibid.

4 sameeragunarathne (username), "How do Shima Seiki Machines work?" (comment in forum), published May 25, 2015. https://github.com/fossasia/2018.fossasia.org/issues/1.

5 Soft Byte Ltd., "DesignaKnit 8," accessed October 29, 2018. https://www.softbyte.co.uk/designaknit.htm.

6 Soft Byte Ltd., "DesignaKnit Cable Links," accessed October 29, 2018. https://www.softbyte.co.uk/cablelinks.htm.

7 Soft Byte Ltd., "DesignaKnit 8."

**Figure 3.3. Kniterate, Photo of Kniterate knitting machine, accessed May 3, 2019. https://www.kniterate.com.**

## //Kniterate

Kniterate (figure 3.3) is a whole-garment knitting machine that, at 9,499 USD,[8, 9] is significantly more affordable than a Shima Seiki model. Kniterate was funded on Kickstarter and is yet to be released as of May 2019.[10] The product markets itself towards both hobbyists and business owners.[11] An FAQ indicates that the machines will accept "k-code" files (this is different from Knitout files), and they have began to document the file specification online.[12]

Since it has not yet been released, I am unable to evaluate the software component of Kniterate to assess how well it meets users needs. Their FAQ indicates that the software is currently template-based, which may mean that the silhouettes of garments made on Kniterate software are challenging or impossible to customize.[13] In order to learn more about the software and hardware, I visited the Kniterate office in London for a demonstration.

From the demonstration, the hardware looked very promising. However, the software was not yet available to test. The developers indicated an intention for an editor that allows editing at the stitch level, and indicated a possible intention to move away from the template model indicated in their FAQ.

Though it evolved out of an open source project called "Open Knit,"[14] Kniterate is close-sourced,[15] meaning it might be challenging for users to develop their own functions if the included software doesn't fit their needs.

8 Kniterate, "Automated Knitting For Your Workshop," accessed October 29, 2018. https://www.kniterate.com.

9 Kniterate, "Meet Kniterate," accessed October 29, 2018. https://www.kniterate.com/product/kniterate-the-digital-knitting-machine.

10 Kniterate, "Timeline Update IV, Software Release and Knitting in London," published December 20, 2018, https://www.kniterate.com/2018/12/20/timeline-update-iv-software-release-and-knitting-in-london.

11 Kniterate, "Automated Knitting For Your Workshop."

12 Kniterate, "K-code," accessed February 21, 2018. https://docs.google.com/document/d/1-wgHkK0E-fa7u-r1F0kWEtqTTGle-GUSMdC5zQKS2_vms/pub.

12 Kniterate, "Automated Knitting For Your Workshop."

13 Kniterate, "Meet Kniterate."

14 Kniterate, "Knitting machines made for everyone," accessed October 29, 2018. https://www.kniterate.com/about.

15 Kniterate, "Meet Kniterate."

# //State of the Art:
# Open-source Technology

This subsection lists hardware and software for machine knitting developed under an open-source model.

# Open-source Technology

## //Carnegie Mellon Textiles Lab

Jim McCann leads the Textiles Lab at Carnegie Mellon University, with work contributed by students and faculty.[16] They have done a variety of projects with the Shima Seiki whole-garment machines, some of which will form the basis for my work.

### /*Knitout File Format*/

This file specification is a relatively simple way to write knitting code that can be made readable by Seiki whole-garment knitting machines, when compiled by another software program created by the Carnegie Mellon Textiles Lab.[17] Knitout files are designated as either .Knitout or .k files. To my knowledge, this is the only non-proprietary way to design for Shima Seiki whole-garment knitting machines. As such, I will be using Knitout code as the basis for my work.

16 "The Carnegie Mellon Textiles Lab," The Carnegie Mellon Textiles Lab, accessed October 28, 2018. https://textiles-lab.github.io.

17 "Knitout" (Github code repository), last updated March 8, 2018. https://github.com/textiles-lab/Knitout.

18 James McCann, Lea Albaugh, Vidya Narayanan, April Grow, Wojciech Matusik, Jennifer Mankoff, and Jessica Hodgins. "A compiler for 3D machine knitting." ACM Transactions on Graphics (TOG) 35, no. 4 (2016): 49.

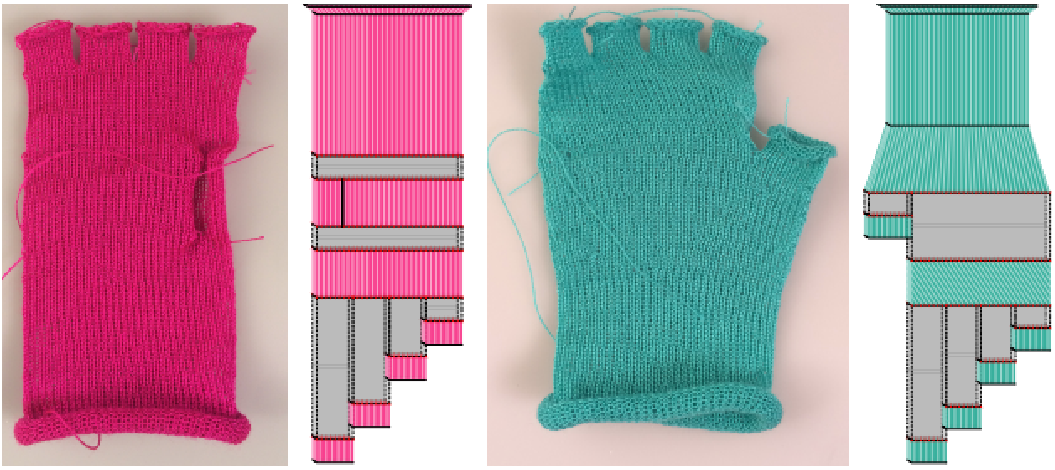


**Figure 3.4 Photos of fingerless gloves beside the sketches used to create them.**

(James McCann et al., Figure 14 in "A compiler for 3D machine knitting." ACM Transactions on Graphics (TOG) 35, no. 4 (2016): 49.)

### /*A Compiler for 3D Machine Knitting*/

In this project, McCann and colleagues from Carnegie Mellon, MIT and Disney Research developed a means of compiling colour-coded 2D sketches of primitive shapes into 3D forms.[18] Figure 3.4 shows examples of the software in use and its output.

**Figure 3.5. 3D models (bottom) and the knit models created based on them (top). Note that the rabbit is stuffed with a foam model to give it its precise shape.**

(Narayanan et al., Figure 19 from "Automatic machine knitting of 3D meshes," ACM Transactions on Graphics (TOG) 37, no. 3 (2018): 35.)

## /*Automatic Machine Knitting of 3D Meshes*/

Here, the Carnegie Mellon Textiles Lab developed software to convert 3D models to knitted objects, as demonstrated in figure 3.5.[19]

A version of this software has been made open-source.[20] The interface is mainly based on the command line, and does not support designing 3D objects, only ensuring that the output code is valid. A minimal visual interface allows the user to make minor changes to the output form, such as adding holes and demarcating the ends of the knit form, and to visualize how the object will be knit.

I tested this software but was unable to create a knit structure that the SDS-ONE APEX 3 deemed capable of knitting without significant errors, even using the Textiles Lab's own sample files.

19 Vidya Narayanan, Lea Albaugh, Jessica Hodgins, Stelian Coros, and James McCann, "Automatic machine knitting of 3D meshes," ACM Transactions on Graphics (TOG) 37, no. 3 (2018): 35.

20 "autoknit" (Github code repository), last updated September 6, 2018. https://github.com/textiles-lab/autoknit.

# //All Yarns Are Beautiful

All Yarns Are Beautiful (AYAB) is a hardware component and software program that can be used to modify Brother knitting machines.[21] Figure 3.6 shows both hardware and software components in use.[22] The software program features an image-to-pattern tool.[23] Like DesignaKnit 8, AYAB is built for consumer-grade knitting machines, and so cannot support designing for the unique capabilities of whole-garment knitting. Notably, AYAB is entirely open-source.[24]

21 "AYAB – all yarns are beautiful," AYAB, accessed October 29, 2018. http://ayab-knitting.com.

22 "AYAB Interface," Evil Mad Scientist, accessed November 6, 2018, figure 5. https://shop.evilmadscientist.com/productsmenu/835.

23 "What is AYAB," AYAB, accessed October 29, 2018. http://ayab-knitting.com/features.

24 "AYAB – all yarns are beautiful."

25 Becky Stern, "Electro-knit," adafruit, last updated October 28, 2018. https://learn.adafruit.com/electroknit.

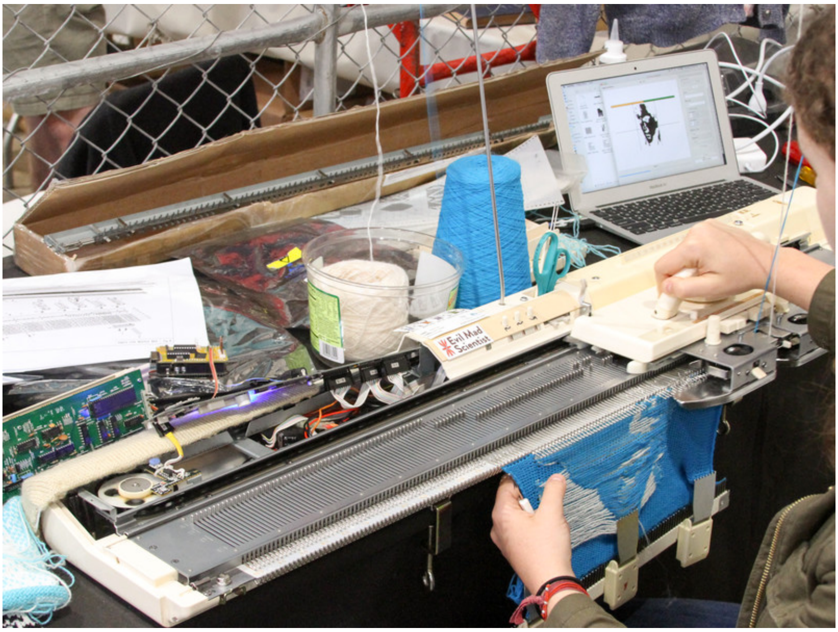



**Figure 3.6. AYAB component installed in a knitting machine.**

(Photo of AYAB Interface, Evil Mad Scientist Webshop, accessed May 3, 2019. https://shop.evilmadscientist.com/productsmenu/835.)

# //Electro-knit

Electronics component manufacturer and "maker" resource Adafruit published a guide for hacking a Brother knitting machine using generic hardware and open-source software.[25] The software allows the user to convert a two-colour image into a colour pattern on your knit. They call their method "Electro-knit." As with AYAB and DesignaKnit 8, Electro-knit cannot create whole-garment knitted patterns.

//State of the Art:

# Brands Working with Whole-garment Technology

A number of fashion brands work with whole-garment knitting, but many don't advertise this as a feature of the garment. This sub-section lists some companies that have incorporated whole-garment technology into their business strategies in innovative ways, or who are vocal about their use of the technology.

# Brands Working with Whole-garment Technology

## //Ministry of Supply

This fashion brand hosts what they call the "3D Print-Knit Shop" at one of their flagship stores (see figure 3.7).[26] Initially, customers were only able to order custom blazers knitted on-site to their specifications (such as colour, and cuff-style, though they still had to choose from standard sizes).[27] One of the more recent additions to the 3D Print-Knit Shop is a sweater customized to the wearer's thermal profile.[28] For this product, customers have their body scanned and a computer program identifies where they would benefit from added ventilation.[29]

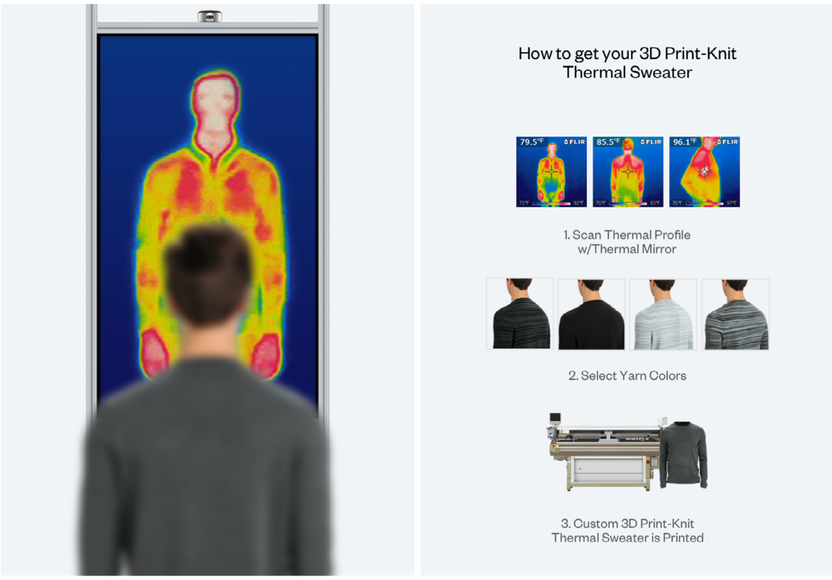



**Figure 3.7. Diagram from Ministry of Supply demonstrating the 3D Print-Knit process.**

(Ministry of Supply, "How to get your 3D Print-Knit Thermal Sweater," Ministry of Supply blog, accessed March 8, 2019, https://ministryofsupply.com/blogs/tested/introducing-our-3d-print-knit-shop.)

## //The Girl and the Machine

The Girl and the Machine is a fashion label based out of the Netherlands.[30] Their brand mission emphasizes the sustainable elements of whole-garment knitting, like reducing waste materials that occur as part of the traditional production process or due to over-production, and reducing the dependence on workers making below living wages.[31] In their first collection, customers could customize their garment by providing their various key body measurements and choosing elements like colour and collar-style.[32]

26 Ministry of Supply, "Introducing Our 3D Print-Knit Shop," Ministry of Supply blog, accessed March 8, 2019, https://ministryofsupply.com/blogs/tested/introducing-our-3d-print-knit-shop.

27 Marc Bain, "Brands see the future of fashion in customized 3D-knitted garments produced while you wait," Quartz, published April 5, 2017, https://qz.com/949026/brands-including-adidas-uniqlo-and-ministry-of-supply-see-the-future-of-fashion-in-on-demand-3d-knitting.

28 Ministry of Supply.

29 Ibid.

30 The Girl and the Machine, "The Girl and the Machine – 3D Printed Knitwear," The Girl and the Machine, accessed March 8, 2019, http://www.thegirlandthemachine.com/en.

31 The Girl and the Machine, "The Girl and the Machine @ Mastery," The Girl and the Machine, published May 4, 2018, http://www.thegirlandthemachine.com/pers/the-girl-and-the-machine-mastery-the-dutch-milano/index.html.

32 The Girl and the Machine, "3D knitting on demand: revolution in clothing," One Planet Crowd, accessed March 8, 2019, https://www.oneplanetcrowd.com/en/project/171844/description.

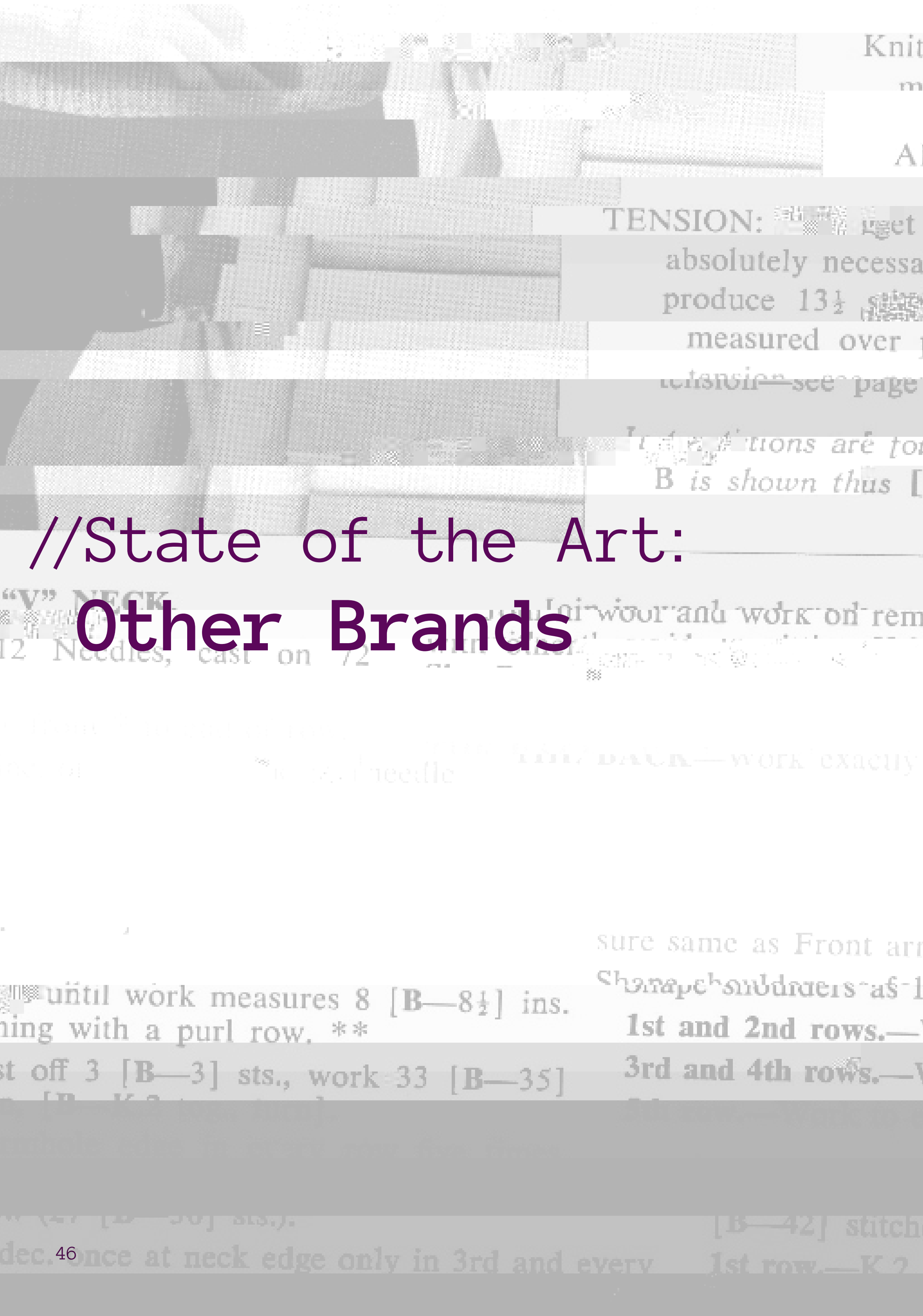
## //Uniqlo

Uniqlo doesn't offer customization options like the other companies listed in this section. Its 3D Knit collection instead emphasizes the comfort provided as a result of seamless construction, as shown in figure 3.8.[33]

33 Uniqlo, "A New Dimension in Knitwear: 3D Knit," accessed March 8, 2019, https://www.uniqlo.com/uk/en/pages/knitwear/3d-knit.


**Figure 3.8. A still image from a video of Uniqlo's 3D Knit ad campaign.**

(Uniqlo, Still at 0:53 from video "3D Knit," accessed March 8, 2019, https://www.uniqlo.com/uk/en/pages/knitwear/3d-knit.)



# //State of the Art: **Other Brands**

Throughout my horizon scan, I identified a number of companies working with themes that are relevent to my project—such as mass customization and open-source development—though they do not use whole-garment technology.

# Other Brands

**Figure 3.9. A user customizing a sweater using knit for you's interface.**

(Adidas, Still at 0:16 from video "Adidas: knit for you," accessed March 8, 2019. http://adidasknitforyou.com.)

## //Adidas

In 2017, Adidas participated in "knit for you": a research project backed in part by the German government.[34] In a pop-up store, customers were able to co-design and purchase custom sweaters. Customers designed the sweater through a system where patterns were projected onto a plain sweater they wore in a designated room. They could use hand gestures to modify the projected pattern.[35] They were able to further customize the pattern on a computer screen afterwards, as shown in figure 3.9.[36] Customers also had the option to select a standard size or to have their size determined by a body scan.[37] The clothing pieces were then produced from a Stoll flatbed knitting machine and assembled on-site.[38] Customers could return to pick up their items within a few hours.[39]

**3.10. Atacac, Product photo for Atacac's sharewear "Butterfly Tee," accessed May 3, 2019. https://shop.atacac.com/collections/sharewear/products/butterfly-tee.**

## //Atacac

Atacac is a Swedish fashion brand that uses cutting-edge technology in their design, manufacturing, and marketing processes. Of particular interest to my work is their sharewear collection (see figure 3.10). This collection consists not of garments users can purchase, but rather clothing patterns developed by Atacac that users can download, print, and sew themselves. sharewear is licensed under a creative commons license.[40]

34 "Adidas explores localised production with 'Knit for You' pop-up store," Knitting Industry, published April 10, 2017, https://www.knittingindustry.com/adidas-explores-localised-production-with-knit-for-you-pop-up-store.

35 Ibid.

36 Emma Thomasson, "Adidas takes the sweat out of sweater shopping with in-store machine," Reuters, published March 20, 2017, https://www.reuters.com/article/us-adidas-manufacturing-idUSKBN16R1TO.

37 Ibid.

38 "Adidas explores localised production."

39 Ibid.

40 Atacac, "Butterfly Tee," Atacac Webstore, accessed March 8, 2019, https://shop.atacac.com/collections/sharewear/products/butterfly-tee.

## //KnitYak

KnitYak is a specialty scarf brand by maker Fabienne Serriere.[41] KnitYak sells scarves with algorithmically designed motifs.[42] When customers purchase a scarf, they also receive the source code used to generate their specific scarf.[43]

## //Unmade

Unmade is a fashion technology platform based in London. They have partnered with brands such as MoMA and Opening Ceremony.[44] Unmade's platform allows customers to customize the motifs on a garment by modifying an existing pattern (for example, in the online demo shown in figure 3.11, users drag their cursor along a sweater with a grid pattern to distort the grid).[45] Unmade's system generates unique technical construction documents for each garment ordered, allowing manufacturers to support mass customization.[46]

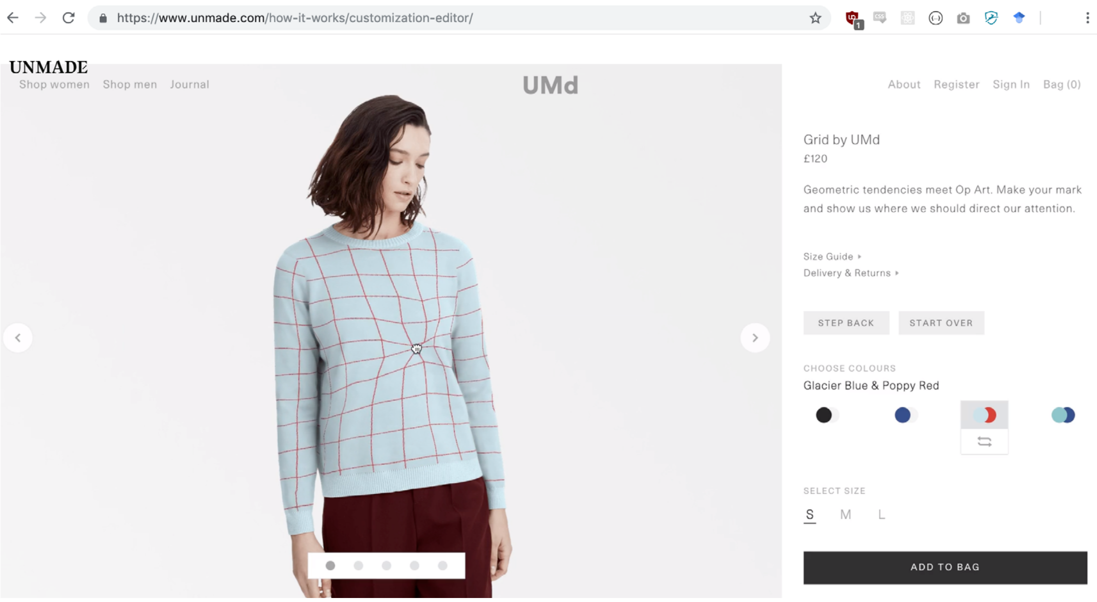



**Figure 3.11. Demonstration video of Unmade's interface.**

(Unmade, Still from demonstration video for customizing Grid by UMd shirt, accessed May 3, 2019. https://www.unmade.com/how-it-works/customization-editor.)

41 KnitYak, "About KnitYak," KnitYak, accessed March 8, 2019, https://knityak.com/pages/about-knityak.

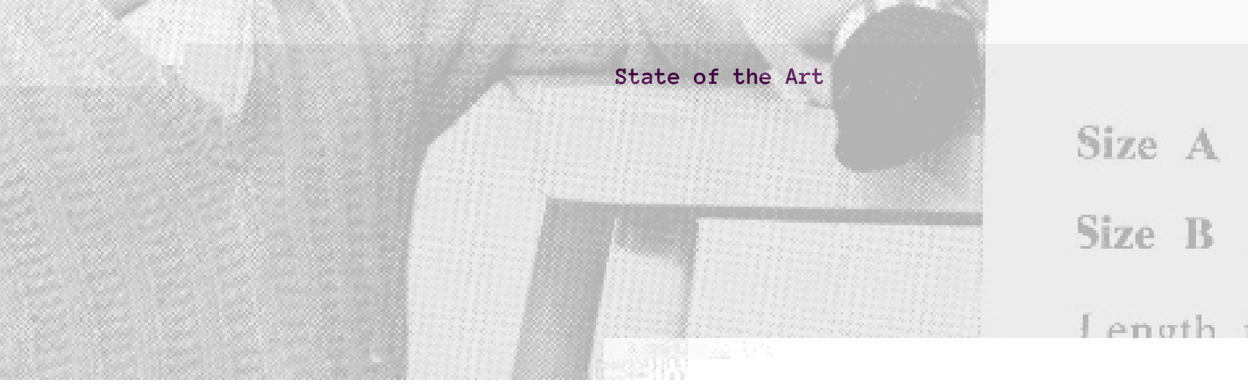
42 KnitYak, "KnitYak: Custom mathematical knit scarves," Kickstarter, accessed March 8, 2019, https://www.kickstarter.com/projects/fbz/knityak-custom-mathematical-knit-scarves/description.

43 KnitYak, "About KnitYak."

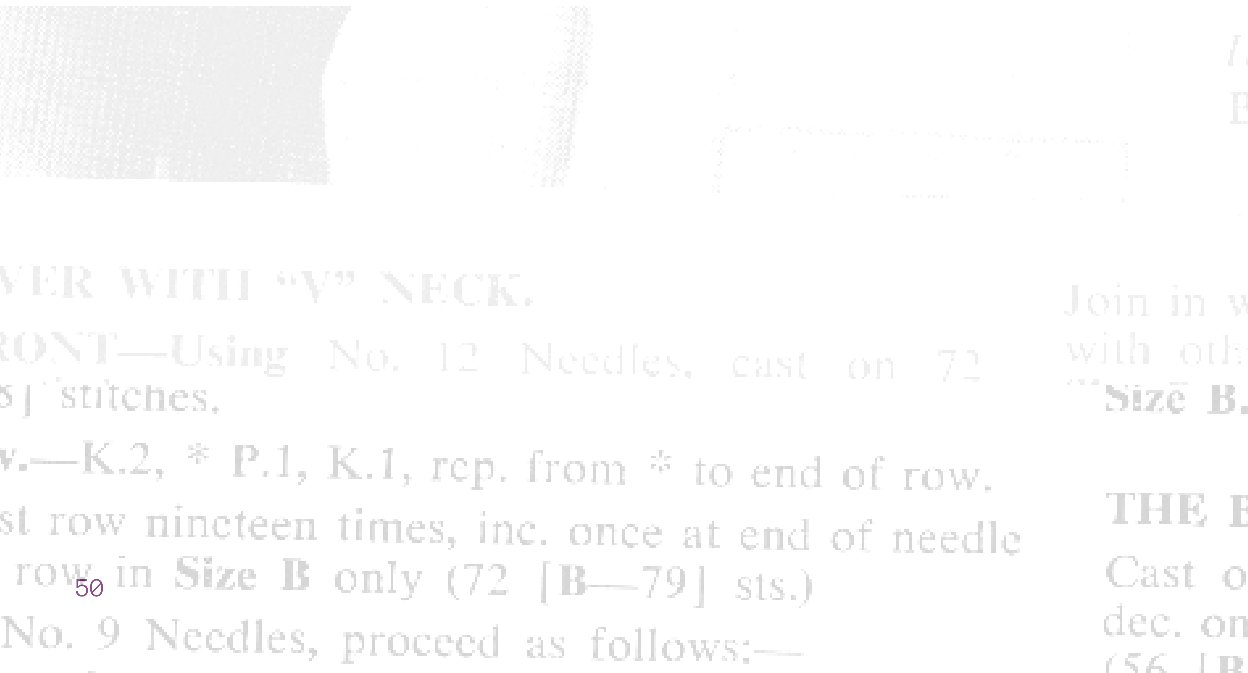
44 Unmade, "Home," Unmade, accessed March 20, 2019, https://www.unmade.com.

45 Unmade, "Home."

46 Unmade, "Factory OMS," accessed March 20, 2019, https://www.unmade.com/how-it-works/factory-oms.




# //State of the Art: Artists



Artists, makers and crafters working with technology and knitting in ways that don't fall neatly into the other categories.

# Artists

## //Andrew Salomone

Andrew Salomone is an artist and maker who often works with different types of textiles and technology. He has worked with Adafruit's Electro-knit hacked knitting machines to produce projects where he converts images to knit patterns.[47] For example, his "Identity-Preserving Balaclava," shown in figure 3.12, features a knitted reproduction of a photo of his own face.[48]

**Figure 3.12. Andrew Salomone wearing his Identity-Preserving balaclava.**

(Andrew Salomone, "Machine Knit Identity-Preserving Balaclava," yarn, December 30, 2010, photo by Becky Stern. http://andrewsalomone.com/blog/2010/12/30/machine-knit-identity-preserving-balaclava.)

## //Freddie Robins

Freddie Robins is an artist and educator at the Royal College of Art in the textiles department.[49] In her collection "The Perfect," Robins created a set of life-size human figures with a Shima Seiki whole-garment knitting machine. One example can be seen in figure 3.13. This project is meant to explore the tension between an appreciation for the unique qualities of handmade goods, and the artist's desire for the perfectly error-free finish enabled by digital technologies.[50]

47 Andrew Salomone, "Works," accessed March 10, 2019, http://andrewsalomone.com/blog/works.

48 Andrew Salomone, "Machine Knit Identity-Preserving Balaclava," published December 30, 2010, http://andrewsalomone.com/blog/2010/12/30/machine-knit-identity-preserving-balaclava.

49 Freddie Robins, "About," accessed March 20, 2019, http://www.freddierobins.com/about.php.

50 Freddie Robins, "The Perfect," published May 2, 2007, http://www.freddierobins.com/blog/the-perfect.

Figure 3.13. Freddie Robins, “The Perfect - Alex,” machine knitted wool and acrylic yarn, 2007, http://www.freddierobins.com/blog/the-perfect.

## //Siren Elise Wilhelmsen

Siren Elise Wilhermsen's "365 Knitting Clock" (figure 3.14) stitches one new row of stitches every 24 hours.[51] At the end of a year, it produces a two meter long scarf so that the "past can be carried out into the future."[52] "365 Knitting Clock" is intended to visualize time as a more tangible concept.[53]

51 Siren Elise Wilhelmsen, "365 Knitting Clock," created 2010, http://www.sirenelisewilhelmsen.com/#365knittingclock.

52 Ibid.

53 Ibid.

**Figure 3.14. Siren Elise Wilhelmsen, "365 Knitting Clock," wood, wool, acrylic, electrical components, created 2010, http://www.sirenelisewilhelmsen.com/#365knittingclock.**

**Figure 3.15. Ebru Kurbak and Mahir M. Yavuz, "News Knitter," yarn, created 2007–2008, http://casualdata.com/newsknitter.**

## //Ebru Kurbak and Mahir M. Yavuz

Kurbak and Yavuz's "News Knitter" converts data gathered from news RSS feeds into visual patterns that are then printed onto sweaters (see figure 3.15).[54] Each sweater represents news taking place over a particular time period. I wasn't able to find much information online as to why the makers elected to design sweaters specifically, except for a poster where Kurbak and Yavuz identify the goal of materializing news streams, which they consider ephemeral.[55]

54 Ebru Kurbak and Mahir M. Yavuz, "News Knitter," last updated December 28, 2009, http://casualdata.com/newsknitter.

55 Ebru Kurbak and Mahir M. Yavuz. "News Knitter." In ACM SIGGRAPH 2009 Art Gallery, p. 29. ACM, 2009.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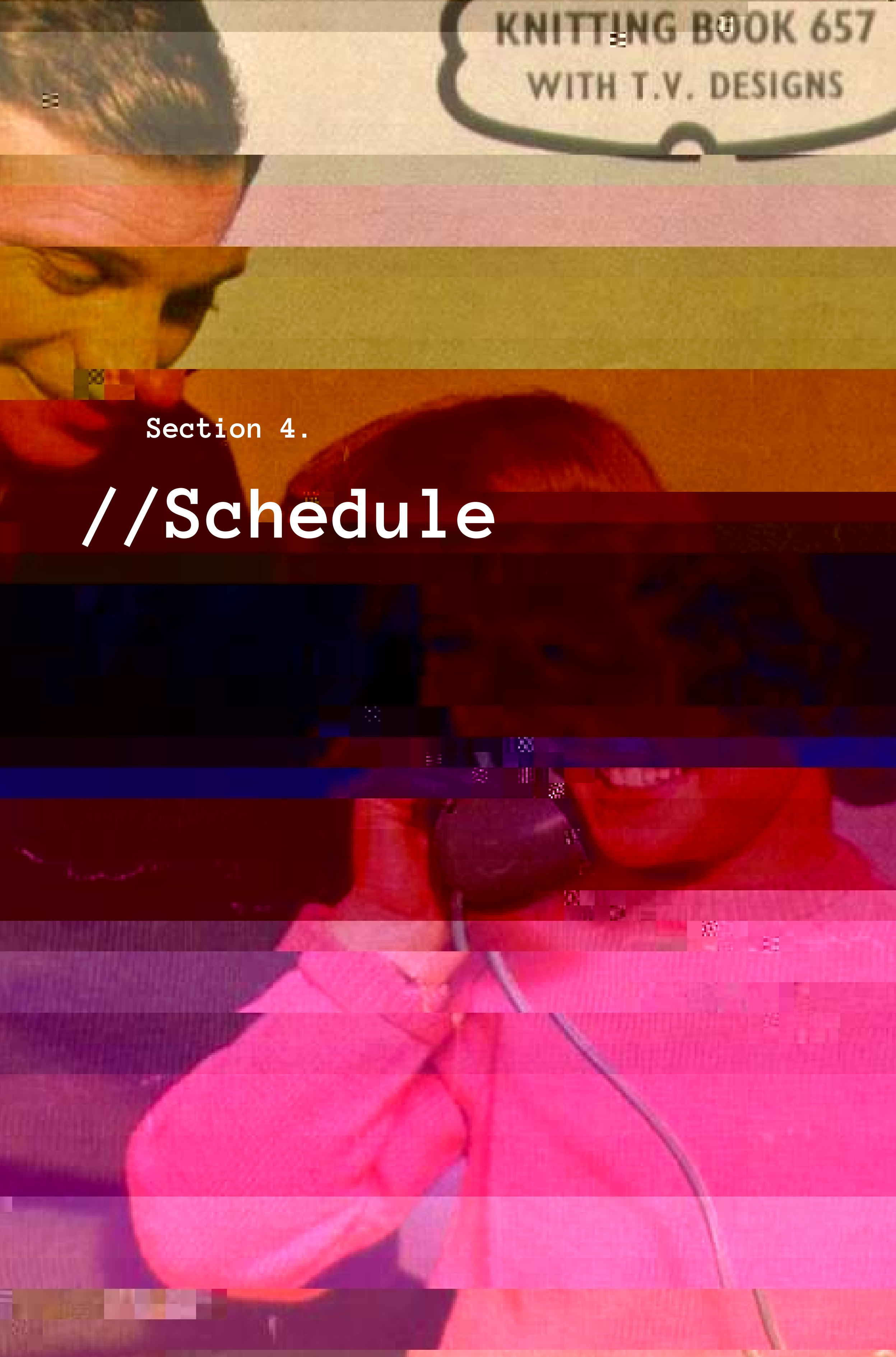



Section 4.

# //Schedule

# Schedule

The Gantt chart below illustrates my schedule for the semester (which spanned January 14 - May 20, not including the final presentation). I opted not to idealize it, and instead detail any delays in order to give a truer representation of my process.

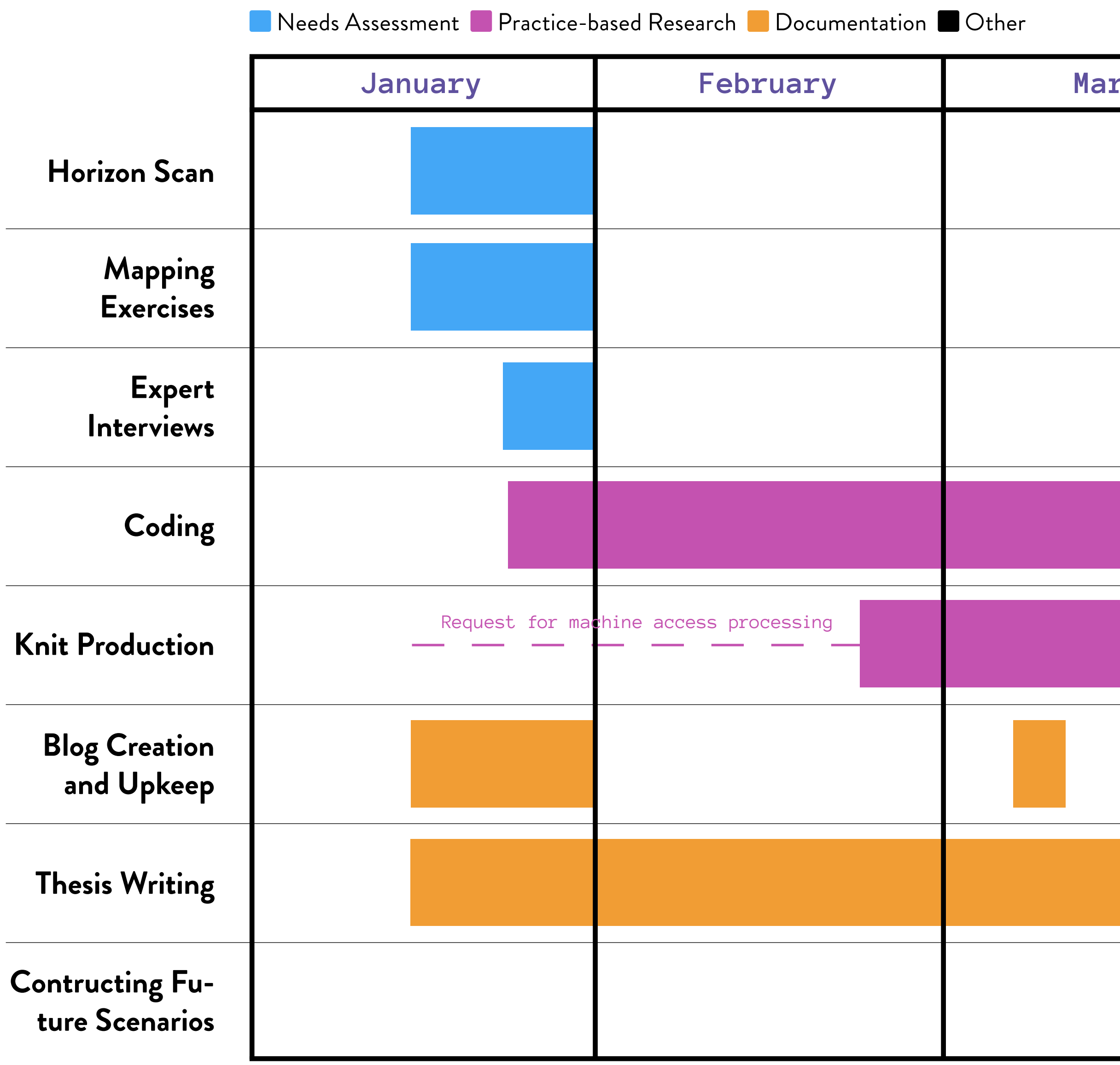
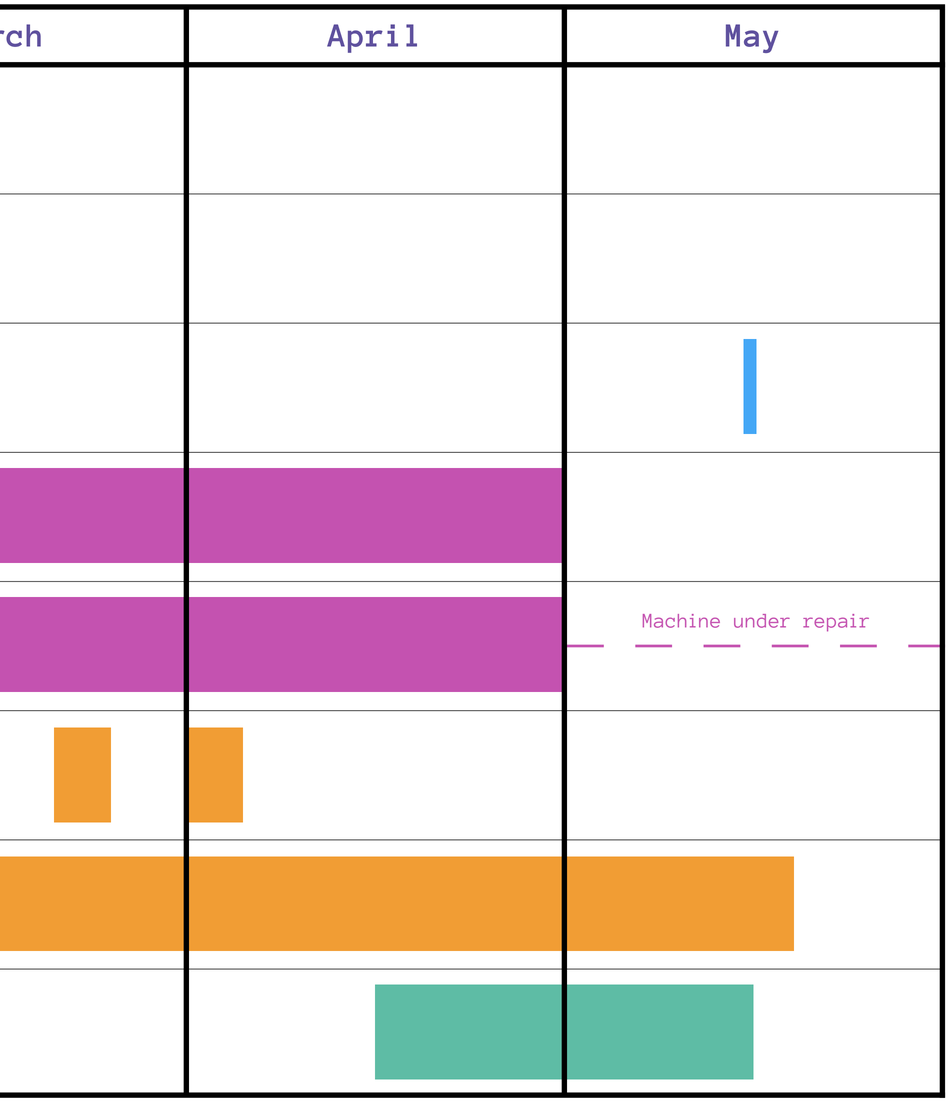
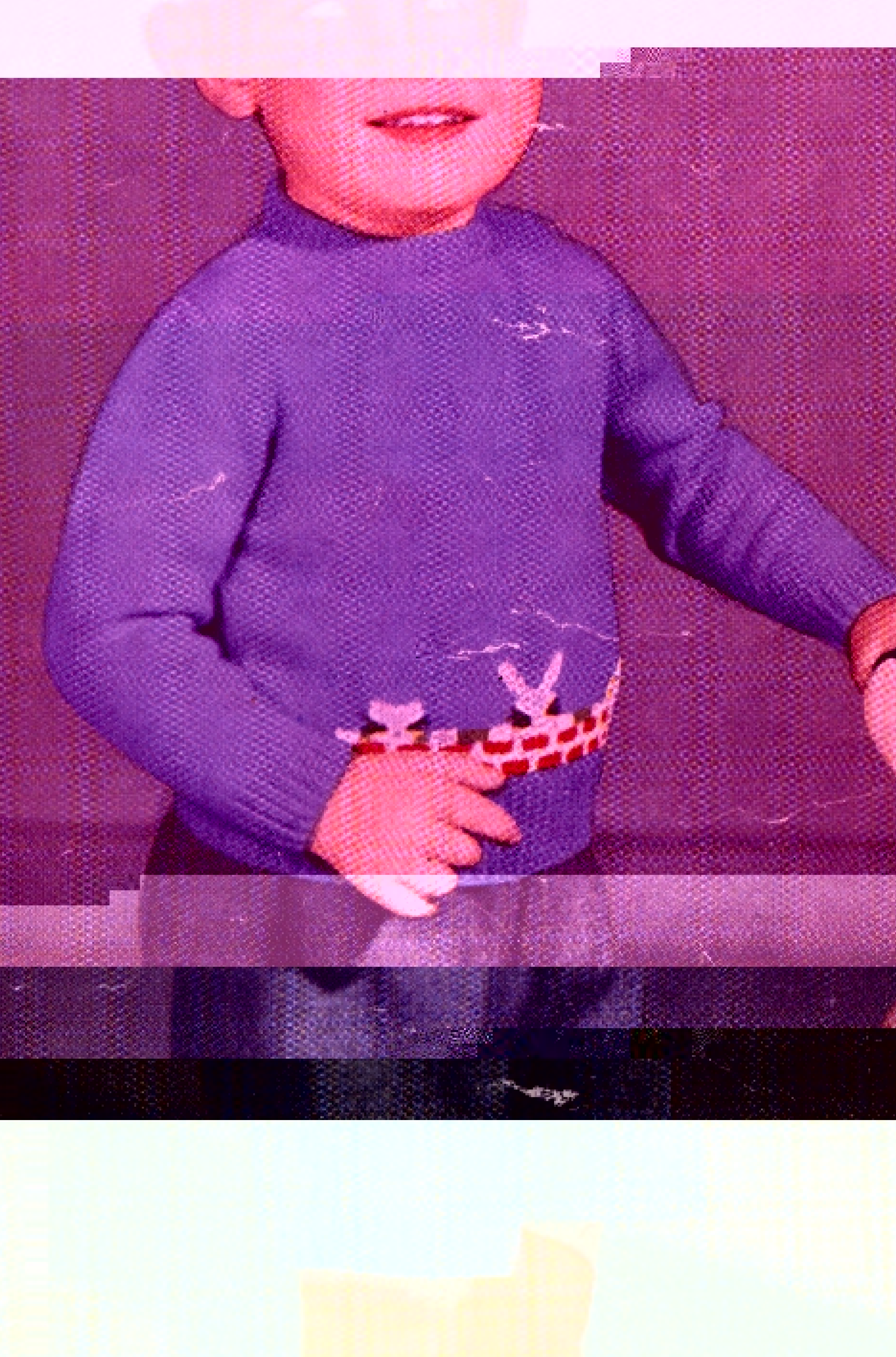



Figure 4.1. Gantt chart representing my schedule for the AHO 2019 Spring semester.


rch
April
May
Machine under repair



Section 5.

# //Needs Assessment

# Needs Assessment

Early in my thesis, I performed a number of needs assessment activities to help determine where my work with whole-garment knitting would be of most use. As discussed in the **Introduction**, my work this semester will consist of primarily practice-based research learning how to use whole-garment knitting machines with Knitout, as this is a necessary precursor to developing a visual interface or other approach to learning. As a result, I am less concerned with how, where and when users will use my work, but rather who will use it, what they will use it for, and why they might be interested.

## //Guiding Questions

The diagram below (figure 5.1) lays out some questions that I considered while determining how to focus my project.


Figure 5.1. Questions I considered when determining how to focus my project during the needs assessment phase.

# //Methods

I employed a number of techniques in order to better understand who would benefit from more accessible whole-garment knitting technology and how.

## /*Horizon Scan*/

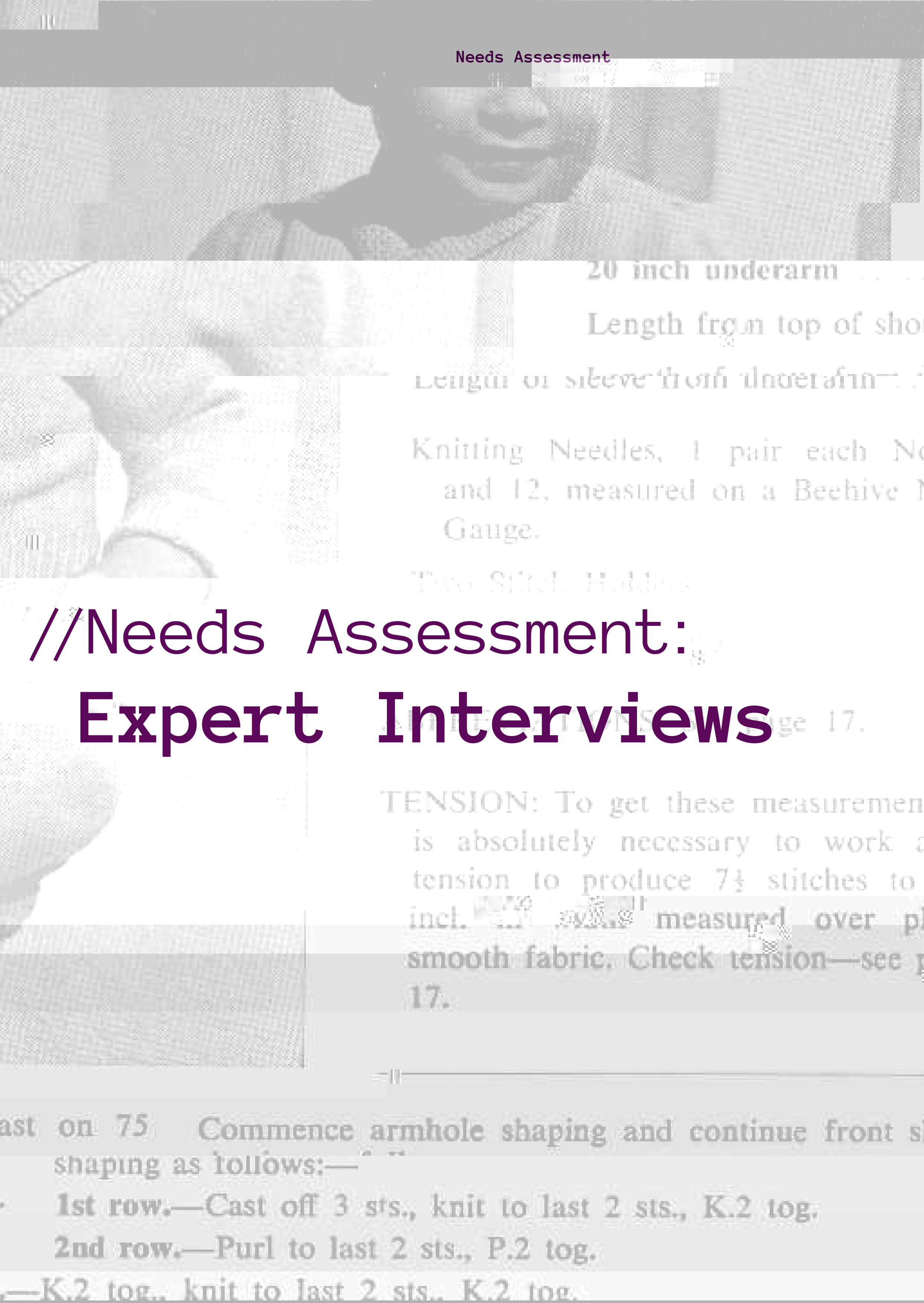
I conducted a horizon-scan of work related to machine knitting and the culture surrounding the activity. I looked at academic texts, artistic works, as well as existing products. The findings I unearthed informed the sections **Digital Machine Knitting**, and **State of the Art**. As such, they are not discussed in detail here except for in the summary.

## /*Expert Interviews*/

I interviewed a number of people working with textiles or fashion in different ways in order to better understand their work and how a more flexible method of whole-garment knitting could benefit their practice. I tried to speak with people from a range of professional backgrounds, working in eductation, industry, and in the arts.

## /*Mapping*/

While conducting these other activities, I created diagrams that attempt to identify existing access to whole-garment knitting, and who would potentially benefit from a more accessible model. I have referred to this activity as "mapping," because they are meant to provide a sort of guide to the knitting landscape (though they do not approach the same level of complexity as many systems maps, or other defined mapping exercises).




# //Needs Assessment:
# Expert Interviews

I spoke to people whose work related in different ways to knitting and textile production. I am incredibly grateful to them for sharing their time and knowledge with me.

My goal in summarizing these conversations is to render these people not as faceless representations of the mass-market fashion industry, independent artistry, and knitwear education. Rather, I hope to convey them as individuals with considerable knowledge in these areas, but who are nonetheless human beings with unique goals and experiences.

# Interview with Hege Meilstrup and Axel Haugan

Hege Meilstrup and Axel Haugan acted as representatives of Varner Group to discuss how more flexible whole-garment knitting technology could be incorporated into Varner's production process. We met January 26, 2019.

## //Location

I met Haugan and Meilstrup at the Varner corporate office in Billingstad. The reception area and lobby looked like a cross between a chic office in Silicon Valley and an upscale department store (see figure 5.1). A scrolling marquee above a reception desk like black lacquered stone greets guests with cycling buzzwords meant to represent Varner's business interests. Further in, past a waist-height gate stylish people passed through with the touch of a key card, huge windows divvied up gray walls so that any visitor could look up at yet more stylish people, working productively alongside clothing racks of next season's must-haves.

## //Profiles

### /*Hege Meilstrup of Varner*/

Hege Meilstrup is the head of design at Varner Group, the parent company of clothing brands such as Cubus, Dressmann, Bikbok and Carlings. On the day we met, she wore an architectural black tunic paired unexpectedly (but fittingly) with a pair of ankle-height Western boots. As head of design at Varner, Meilstrup works with the design teams of every brand to oversee design, buying and parts of logistics.

### /*Axel Haugen of Pioner Labs*/

Axel Haugen heads the design department at Pioner Labs. Pioner is responsible for Varner's digital strategies. Though they are currently occupied with designing a new e-commerce system for Varner that will intelligently inform the manufacturing process, Haugan showed enthusiasm for exploring how emerging technologies could transform the Varner experience.


Figure 5.1. The lobby in the Varner head office in Billingstad.

## //The Conversation

Meilstrup and Haugan came with different knowledge of whole-garment knitting. As part of his work with Pioner Labs, Haugan and his team were starting to identify emerging technologies that could be incorporated in Varner's business strategy in the near future. One of his team members had begun researching whole-garment technology, but, to my knowledge, they weren't yet looking into implementation strategies. He expressed a general enthusiasm towards the technology.

Meilstrup had less knowledge of the technology, other than a brief summary Haugan had sent on my behalf.

Together, we discussed how whole-garment knitting technology had been used in other mass-market companies and their thoughts on if these approaches would be appropriate for Varner.

## /*Sample Making*/

We discussed how whole-garment knitting could be used for creating samples in-house. In Varner's current process, designers design garments and create what are called "tech packs": a set of documents that show a sketch of a finished garment, as well as details on how it is to be created (for example, important measurements, materials to use, explanations of how details should be achieved etc.). These tech packs are sent to manufacturers abroad. Depending on the specifics of the garment, the tech pack might be sent to multiple manufacturers so that the designers can compare samples. Varner usually issues a six-week deadline that the sample must be returned by. This might be shorter if the garment is to satisfy a particular trend that has emerged suddenly.

When asked about in-house or local production, Meilstrup explained that they only have a single sewing machine in head office. Designers mainly use it to alter samples in order to communicate to manufacturers what changes they would like made.

Meilstrup expressed a disinterest for the machines for sample making. The cost of whole-garment knitting machines, and the fact that it takes generally more than an hour to knit a garment were significant dissuasions for her. Overall, she seemed content with Varner's current sample making arrangement and didn't see a real benefit in using whole-garment knitting in this way.

## /*Customization*/

We discussed how whole-garment knitting has been used to create clothing knit to fit the wearer perfectly, or to customize the style of a knit based on the wearer's specifications. Both Meilstrup and Haugan found the concept of custom sizing intriguing.

Haugan raised a concern that people aren't looking for novelty in knitwear, mentioning that simple sweaters with minimal changes apart from colour seem to be offered season after season. Meilstrup countered that women's clothing, particularly styled for a younger demographic, tends to have more variety.

However, producing custom garments to custom dimensions would require money to be invested developing a system that supports that, raising the cost of items to consumers. Despite their interest, this was viewed as a major detractor, given the demographics many of Varner's brands cater to.

## /*Comfort*/

Meilstrup implied that, given the cost and work involved, whole-garment technology was simply not compatible with a fast-fashion business model.

I described how Uniqlo uses the technology without using customization as a selling point, eliminating the need for a customization system. Instead, they emphasize the comfort offered by a seamless garment.

This argument for comfort was received without much interest: Perhaps since Uniqlo already has a campaign centered on seamless comfort, there wouldn't be enough novelty for Varner to pursue the same direction.

## /*In-store Experience*/

Meilstrup and Haugan ultimately seemed uninterested in whole-garment knitting as a standard production method for Varner, but the possibilities of whole-garment knitting remained intriguing.

Though customization was not much of a draw when imagined in the abstract, both Haugan and Meilstrup thought that offering an in-store service where a user could customize a garment through whole-garment knitting would be a compelling draw for customers. In Meilstrup's words: "Flagship stores need to have something extra. To compete in the market, you need to have something extra. It needs to be a go-to place, not somewhere you just pass by. We need to make people curious and interested in what we do."

Both thought an in-store experience might create a more personalized experience, with Haugan likening it to the experience of seeing a tailor.

## /*Sustainability*/

Both Meilstrup and Haugan touched on the sustainability aspects of whole-garment knitting when envisioning the technology as an in-store experience. Haugan identified it as a "macro trend" that consumers are increasingly looking for.  Meilstrup mentioned the prospect of having something made-to-order and made-on-site as reducing the need for transport, and reducing the number of unsold items.

# Interview with Franz Petter Schmidt

I spoke with Franz Petter Schmidt, a textile artist and craftsperson, to learn more about how he negotiates issues relating to collaboration and technology in his practice. Our meeting took place January 28, 2019.

## //Location

We met at Franz Petter Schmidt's studio in the historical Prinds Christian Augusts Minde building complex (see figures 5.2 and 5.3). Scmidt spoke with obvious fondness for the location, particularly as he explained how the courtyard was recently open to the public, better connecting the crafts-people working there and the vulnerable people making use of the services offered in other parts of the complex with the rest of the Oslo community.

Hulking, ancient-seeming machines that bare only incidental resemblance to the sleek knitting machines I've been working with loom over what limited free floor space remains. There's a single wooden table with mismatched wooden chairs near the entrance to the studio: I don't get the impression Schmidt spends much time idle while at his studio. A single rack of elegant, tailored clothing stands next to the table. Only that and Schmidt keep the space from feeling like some kind of panorama from the turn of the century.

## //Profile

As part of his research project Weaving Fabric for Suits, Schmidt immersed himself in the everyday workforce at Tingvoll textile mill in the final months before it ceased production. He also visited other Norwegian fabric mills who are struggling with their identity as textile production becomes increasingly outsourced. While there, he documented the tools, rituals, and stories of the mill, using these as inspiration for fabric to create suits of his own.

Schmidt was thoughtful and reflective throughout our conversation, choosing his words with the care and sense of poetry one might hope for from an artist.

Figure 5.2. Franz Petter Schmidt's studio in Prinds Christian Augusts Minde.

## //The Conversation

My conversation with Schmidt was less focused on how digital machine knitting specifically could impact his craft personally, and more with how some of the values associated with it affects the work progress of artists and craftspeople generally.

### /*Openness and Collaboration*/

In his practice, Schmidt perfers to alternate between collaborative and independent work periods. In our conversation, I identified two types of collaborations he takes part in. There are collaborations with other makers, most recently with performance artist Marianne Heier, and, on multiple occassions with the fashion collective Haikw/. Schmidt says that these types of collaborations challenge him to consider his work through different lenses.

Figure 5.3. Antique textile-creation machines in Scmidt's studio.

Schmidt also creates work of more ephemeral types of collaborations. In Weaving Fabric for Suits, Schmidt developed a rapport with workers at Sjølingstad and Tingvoll fabric mills. Their knowledge and stories from working there for often decades became Schmid's own knowledge.

Schmidt also spoke about how he likes to involve the community in other ways: He gives tours of his studio and exhibits at community spaces. He thinks that open dialogue is an important part of his work. He's also in the process of redesigning his website to provide a more open-source view of his practice, providing dye recipes and details of production methods. In Schmidt's words, "If we don't have time to share information—then we're in trouble."

## /*Digitization*/

Though Schmidt has used digital production methods in the past, such as by using digital techniques to recreate patterns from the archives of old Norwegian textile mills, he stated a strong preference to working with hand tools. He described the reasons for his preference as so:

> It has to do with intimacy. It has to do with time. I need my body to feel like it's a part of it. Some parts of digitization are challenging to follow. I like to trace how things happen. Digital production is fast. It disappears for me.
>
> I think that my whole project is a slow protest to mass production. Time and intimacy is key to relate to the object. It's important to me, and it's important to the object.

This was an interesting, and slightly concerned prospect for me, as I was interested in returning creative control and a sense of agency over making to designers through digital knitting, and I didn't want people from traditional crafts backgrounds to find the technology distancing. I asked him if he thought it was possible to feel an intimacy to making with digital production methods.

He responded that it was possible, but that you have to be able to feel a relationship with the method. For him, an example for a digital production method that he still felt created a sense of intimacy was weaving with TC1 and TC2 digital looms. In this process, the weaving is still by hand but the designer can input an image in from a computer.

## /*Local Production*/

Given the intersection of Schmidt's work with closed and closing textile production facilities, and whole-garment's propsensity for on-demand knitting, we spoke about the current state of local production versus import.

Schmidt emphasized Norway's historically important role in the textile industry, which is now ceasing to exist. He thinks that there's an opportunity now to re-activate the textile industry, by looking to other parts of Europe for inspiration.

He spoke with frustration on the current production process by fashion design companies: "You see these samples from design houses. They ship them back and forth. It's a long distance between production and design. It's a huge problem." Ultimately, though, he empathized with the situation that they're in. He recounted an industry report by a large Norwegian fashion company that acknowledged that they needed to improve their sustainable processes, but could not find a financially viable way of doing so. Schmidt summarized the current situation as being in a bit of a deadlock.

# Interview with Camilla Bruerberg

Unlike my other interviewees, Camilla Bruerberg and I spoke many times throughout the semester. It was hard not to—we were both working in the same office in KHiO's textile department and our schedules frequently overlapped. I learned about Camilla's practice during this time, and many of her thoughts informed my project directions. However, due to scheduling conflicts, I was unable to arrange this interview until May 16, 2019.

## //Location

Though our interview took place over the internet, most of our prior conversations happened in KHiO's digital knitting office. There were many days when we sat across from each other on the two computers sporting SDSONE-APEX3 (figure 5.4), commiserating over the unique interface. While I used the SWG-061N whole-garment knitting machine, Camilla used the larger SIG 123 SV flat knitting machine (figure 5.5). As the semester wore on, Camilla began to fill the room with large containers of custom yarn for her own projects. I didn't mind: she has an excellent sense of colour.

## //Profile

Camilla is a textile artist and fashion designer. She is currently a PhD fellow at KHiO. Her research, which includes the recent exhibition "0011," explores the relationship between the body and nature, and how industrialization and other technological innovations can complicate this relationship.

## //The Conversation

During our interview, we discussed Camilla's research interests in textiles, including her transition from fashion design to a practice that also emphasizes art. I also asked about her experiences using Shima Seiki knitting machines.

### /*The Ethics of Fast Fashion*/

When Camilla first decided to study fashion design, she wasn't as concerned by the ethical concerns facing the fashion industry. Of course, she says, she was aware of issues like child labour and sweatshops, but she had always

Figure 5.5. The SIG 123 SV knitting machine in KHiO's digital knitting office.

assumed there was still plenty of manufacturing done in Europe.

However, after she started working as an independent designer, both on her own line and as a freelancer for others, she gained new insight into the extent of ethical issues in the textile industry. Even as fashion companies continue to profit and grow, the margins for factory workers remain paltry. At the same time, issues related to climate change, and the overproduction rampant in the fashion industry, feel increasingly dire.


Figure 5.5. The computers featuring SDS-ONE APEX3 in KHiO's digital knitting office.

Camilla addresses some of these concerns in her research, both in form and production method. In 0011, installations resembling deconstructed sweaters are decorated with motifs of insects nearing extinction due to chemical sprays. Camilla says viewers are meant to reflect on the production of their clothing. Production-wise, she noted the environmental benefits of digital machine knitting for being able to knit on demands and with minimal waste. She saw this, and the machines' potential to create custom clothing, as making them well suited as a way of bringing manufacturing back to Western countries.

## /*Community Engagement*/

Camilla reflected on a need for consumers to be closer to the production of the things they buy, which she sees as the complete opposite of how the clothing industry is today. She touched upon this again later in our conversation, when I asked her about the emotional intimacy we feel (or don't) towards our clothing. She acknowledged that she thinks that people largely don't feel connected to their clothing, and contrasted it with the tailoring that used to be the norm many years ago. She described the process of having custom clothing made just for you, and how the experience could impart a sense of relationship with both the clothing and the tailor who made it.

Camilla also noted her interest in the pedagogical nature of design. She described how both children and adults should be taught more skills related to making in workplaces and schools. She thinks that these skills can engage our bodies and senses in ways that other ways of learning cannot. Towards the end of our interview, Camilla remarked that her father was a teacher, and her desire to "tell and show" through her work likely comes from him.

## /*Skills, Both Digital and Not*/

I asked Camilla about what drew her to digital machine knitting. She said that, when she first started as a student, she was drawn to how perfectly the manual knitting machines knitted. These machines felt like they enabled "endless possibilities with the yarn." As the textile department was upgraded, Camilla tried her hand at the new equipment, always excited by the potential offered by each new machine. Her drive to master the SIG 123 SV seems to be motivated by the same sense of wonder.

She also sees her skills with digital knitting technology and background as a workshop manager as defining traits of her practice. Through her work, she wants to explore what it means to be a designer who also has considerable technical knowledge. She wonders, what unique skills do these grant her?

## /*Experience with Digital Knitting Machines*/

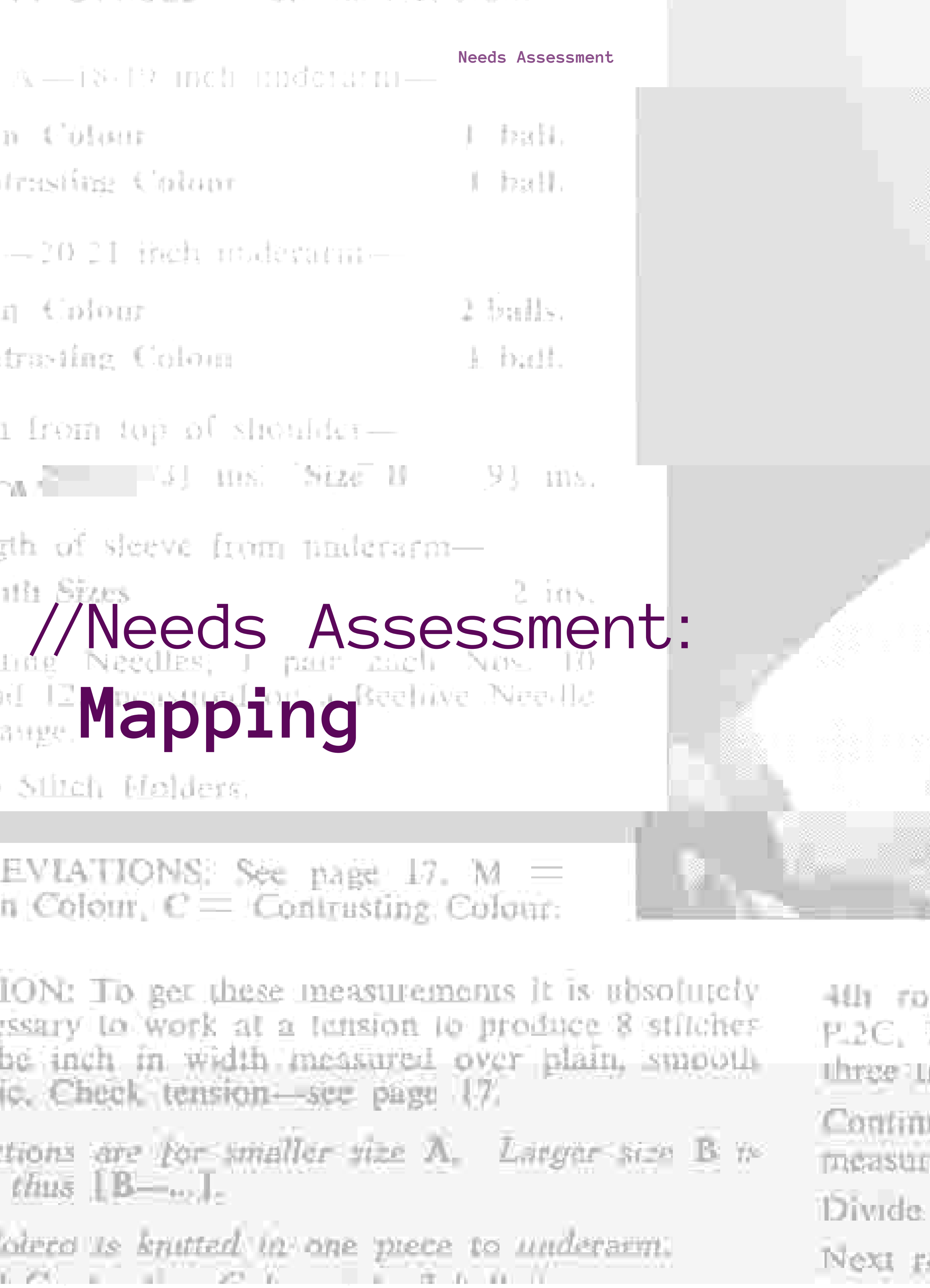
Since Camilla was my only interviewee with experience working with industrial knitting machines, I spent a lot of time asking about her design process.

She described the software as "frustrating" and "unintuitive," even with the amount of experience she has. The only way of really unlocking the full potential of the software, in her opinion, is to train with it and do nothing else for five years.

Camilla attended a training program held by Shima Seiki in Japan as part of her PhD. According to her, without the funding from the PhD, it wouldn't have been financially viable for her to receive the training.

During her time in Japan, she was disappointed that the training didn't include much information on working in 3D. She described the experience as "two weeks learning to make sweaters," and even that wasn't long enough to gain a full understanding. By the end of the training, she said she had barely learned how to do sweaters with stripes—and even those were restricted in placement to a few parts of the sweater.

Camilla doesn't see the technician role dying out in the future. In her opinion, the designer doesn't have to do everything. However, she acknowledges that the official software is a huge gatekeeper preventing users from exploring whole-garment knitting. She stated that work like mine is important in that it lowers that threshold of use for designers.



# //Needs Assessment: **Mapping**

With the knowledge gleaned from interviews and conducting a horizon scan, I made a set of diagrams meant to identify the current and future place for whole-garment knitting.

These diagrams are, of course, highly generalized, but are meant to convey overall tendencies.

# //Knit Production:

## Knitting Today

This diagram is meant to represent knitting production methods in the present day. The "Makers" and "Producers" are types of people I identified throughout my research and were all considered as potential target user groups.

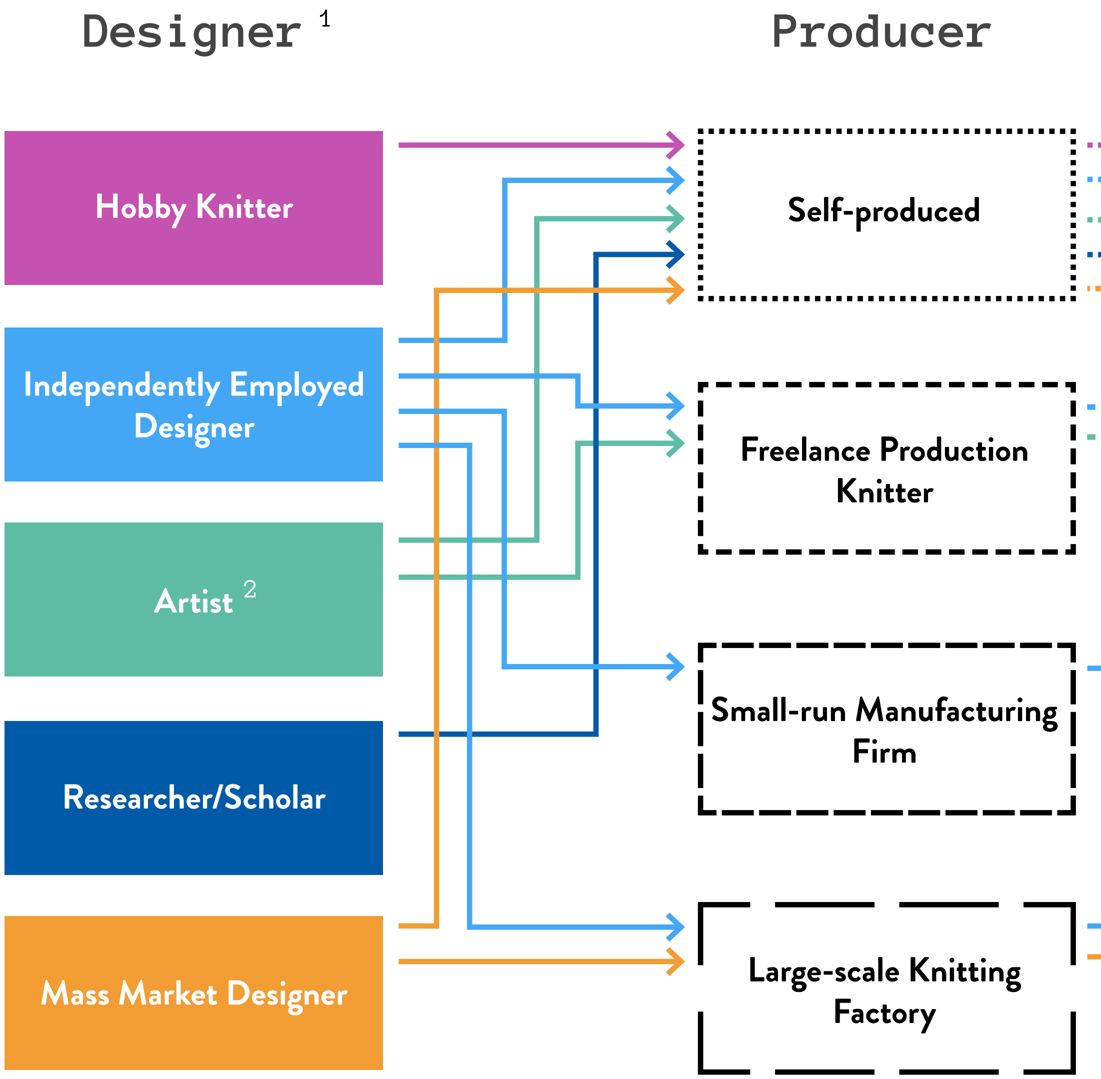
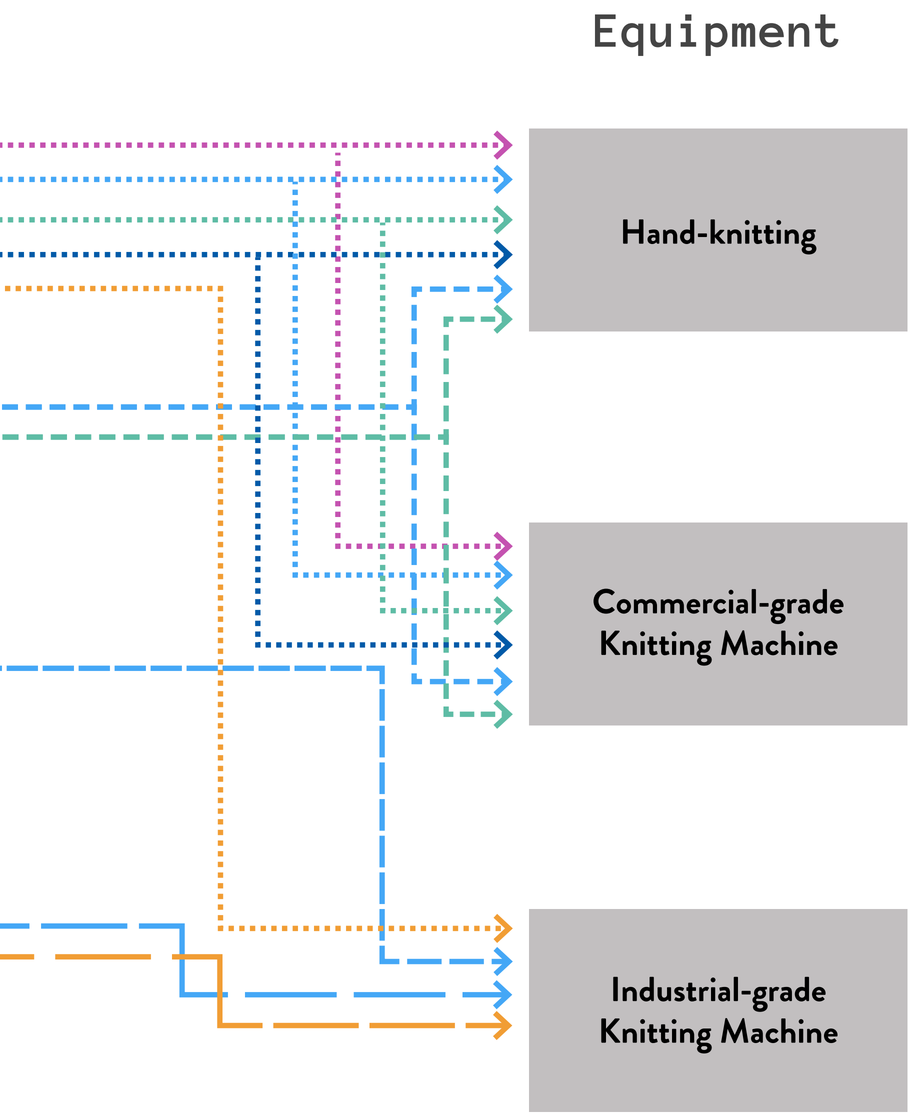



Figure 5.4. Diagram of different production methods used by knitters today.




1 I use the term "designer" in these diagrams to identify the individual that initially conceptualizes the piece that they want to make, whether or not they relate to the title "designer."

2 Artists' and designers' practices vary greatly from individual to individual. I idenyify their production methods from a perspective of "expected" production methods. In reality, artists such as Freddie Robbins have experimented with whole-garment knitting in their practice. See: Freddie Robbins. "The Perfect," accessed February 28 2019, http://www.freddierobins.com/blog/the-perfect.

# //Knit Production:
## The "Laser Cutter" Model

For this diagram, I imagined that whole-garment knitting existed with a comparable availability to a laser cutter to see who *might* use the technology if it were available. This would imply that users might go to a maker space, rapid prototyping business, or public institution with their files to have their item produced. With products like Kniterate on the horizon, this seemed a more likely near future scenario than one involving personal ownership.

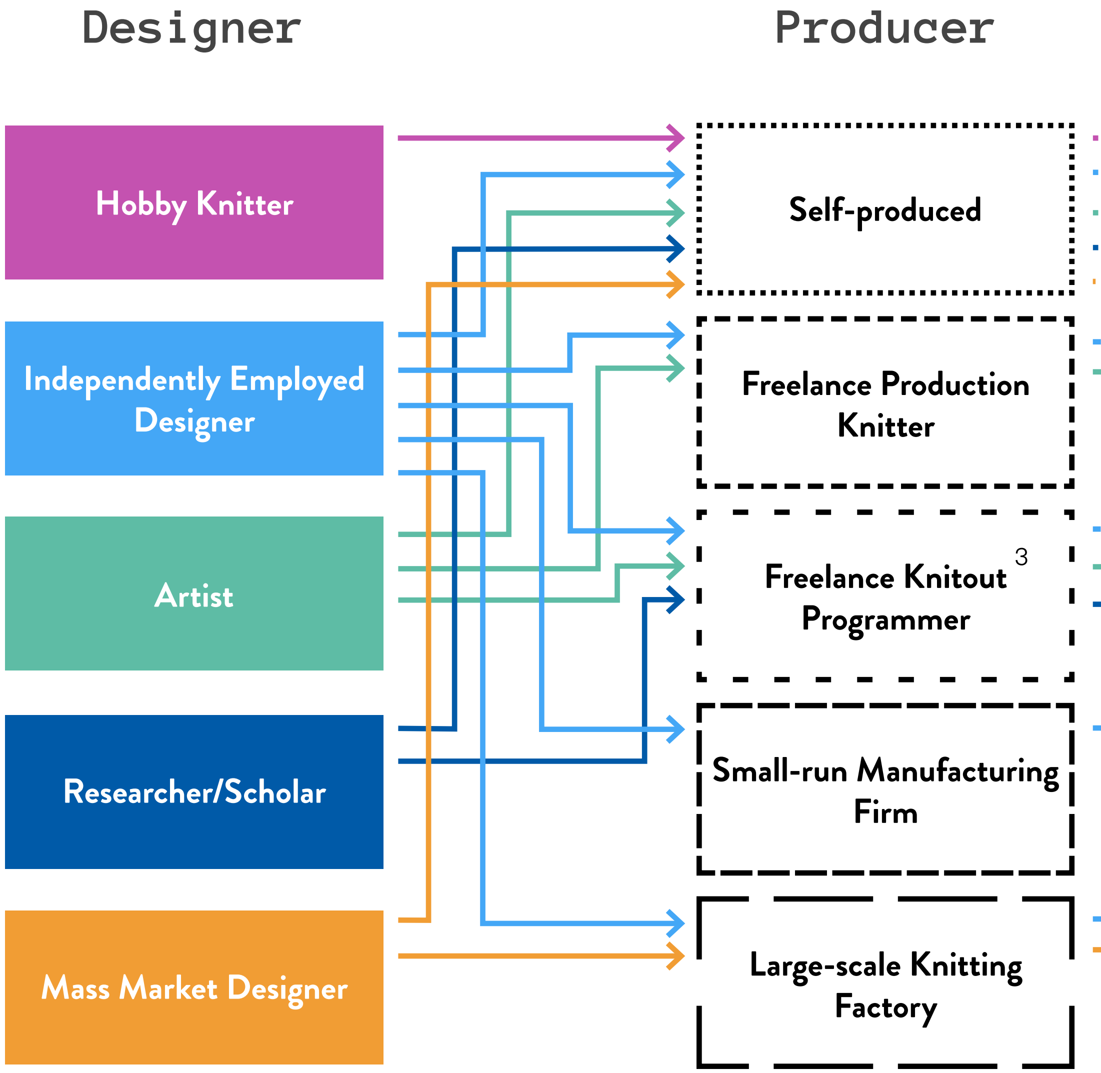
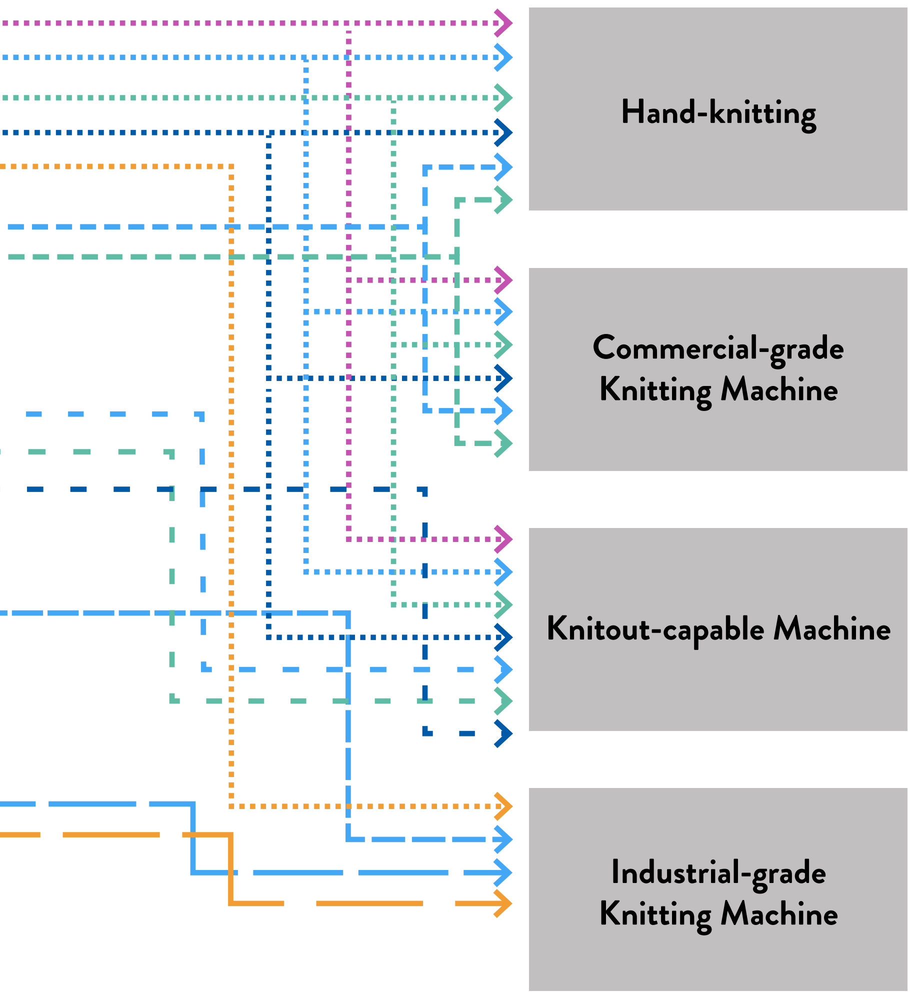



Figure 5.5. Diagram of different production methods potentially used by knitters if whole-garment knitting machines were available at a level comparable to laser cutters.

## Equipment




3 In this diagram, I have invented the role of "Freelance Knitout Programmer." This is a person who is knowledgeable about Knitout programming. A designer who is interested in leveraging whole-garment knitting technology as part of their craft but who cannot program themselves may employ a freelance Knitout programmer to write code for them.

# //Potential Users:
## Who Might Use Knitout?

I thought about the uses of whole-garment knitting technology, including its benefits and limitations, in an attempt to determine what kind of users might benefit most from the technology, and to figure out what kinds of techniques/capabilities to emphasize in my practice-based exploration. In this diagram, I excluded mass-market designers, who might have a much wider range of needs given the amount of items they design and their income.

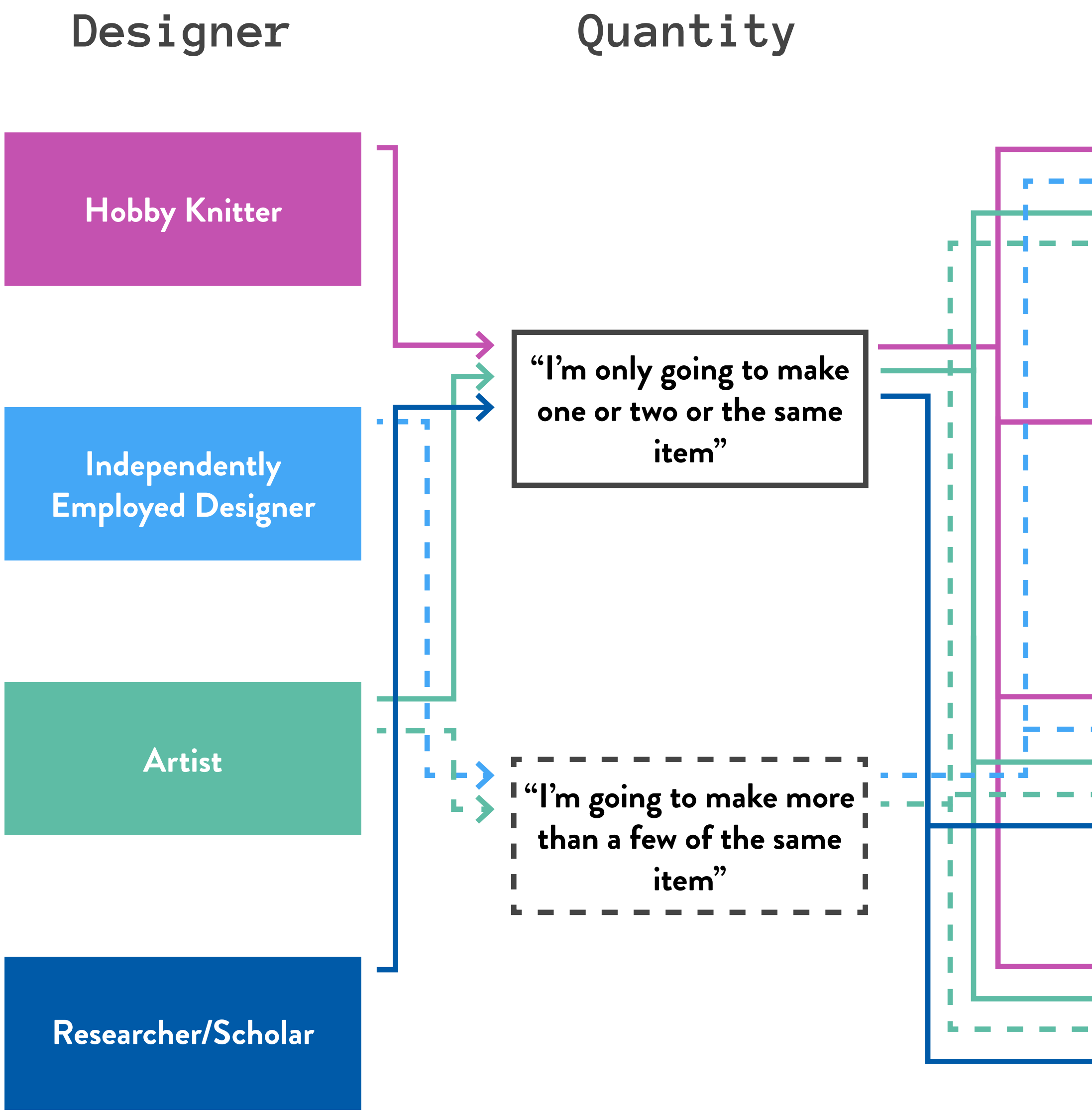
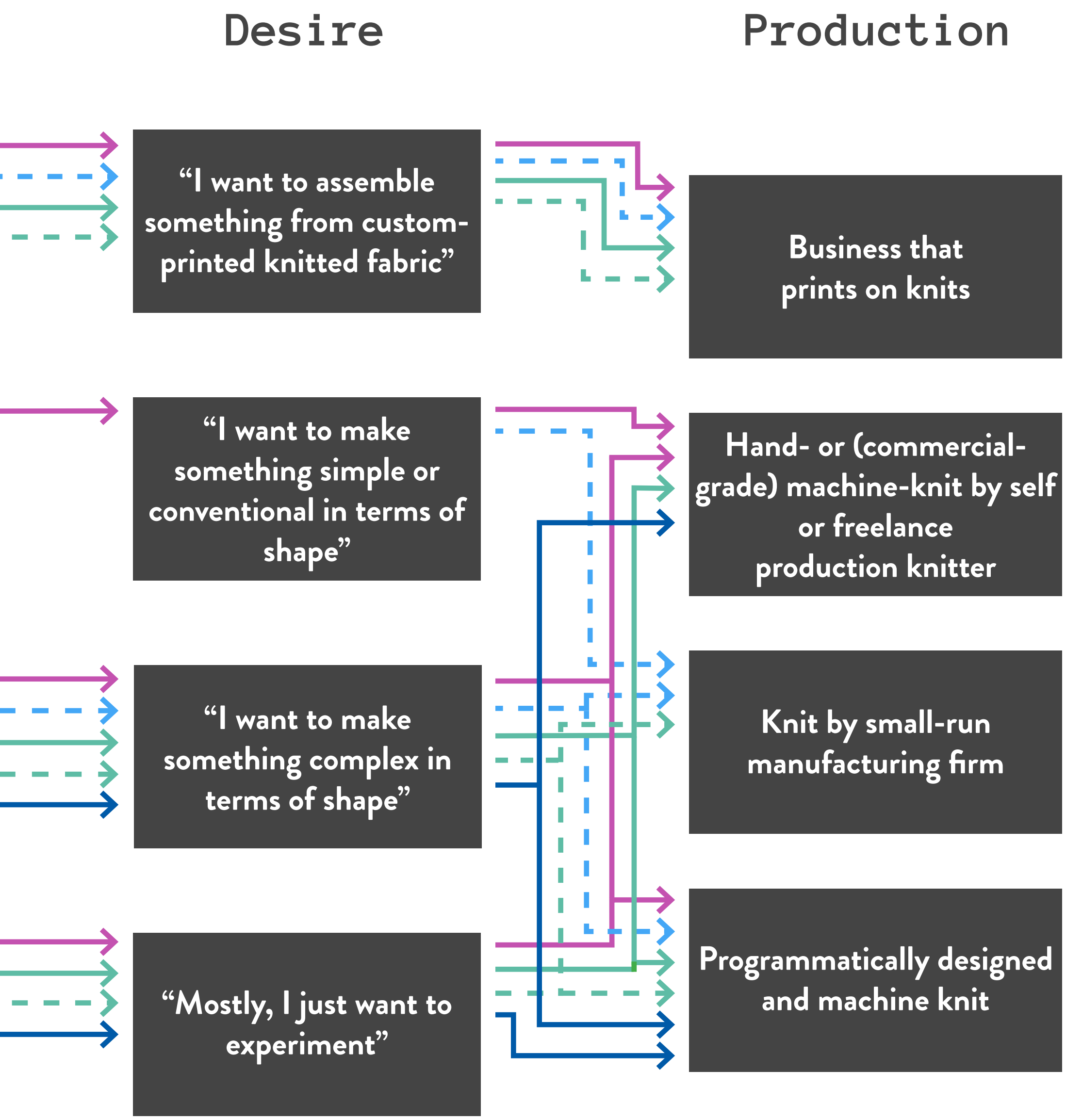



Figure 5.5. Diagram of what users would be drawn to different knit production methods for what uses.


Desire
Production
“I want to assemble something from custom-printed knitted fabric”
“I want to make something simple or conventional in terms of shape”
“I want to make something complex in terms of shape”
“Mostly, I just want to experiment”
Business that prints on knits
Hand- or (commercial-grade) machine-knit by self or freelance production knitter
Knit by small-run manufacturing firm
Programmatically designed and machine knit


# //Needs Assessment: **Summary**

This subsection summarizes my findings from various needs assessment activities, and my choices to determine what kinds of potential users and uses I will design for.

# Summary

At the culmination of these needs assessment activities, I decided to focus on techniques that would enable makers to actualize a unique design goal that isn't well-supported by existing ways of making.

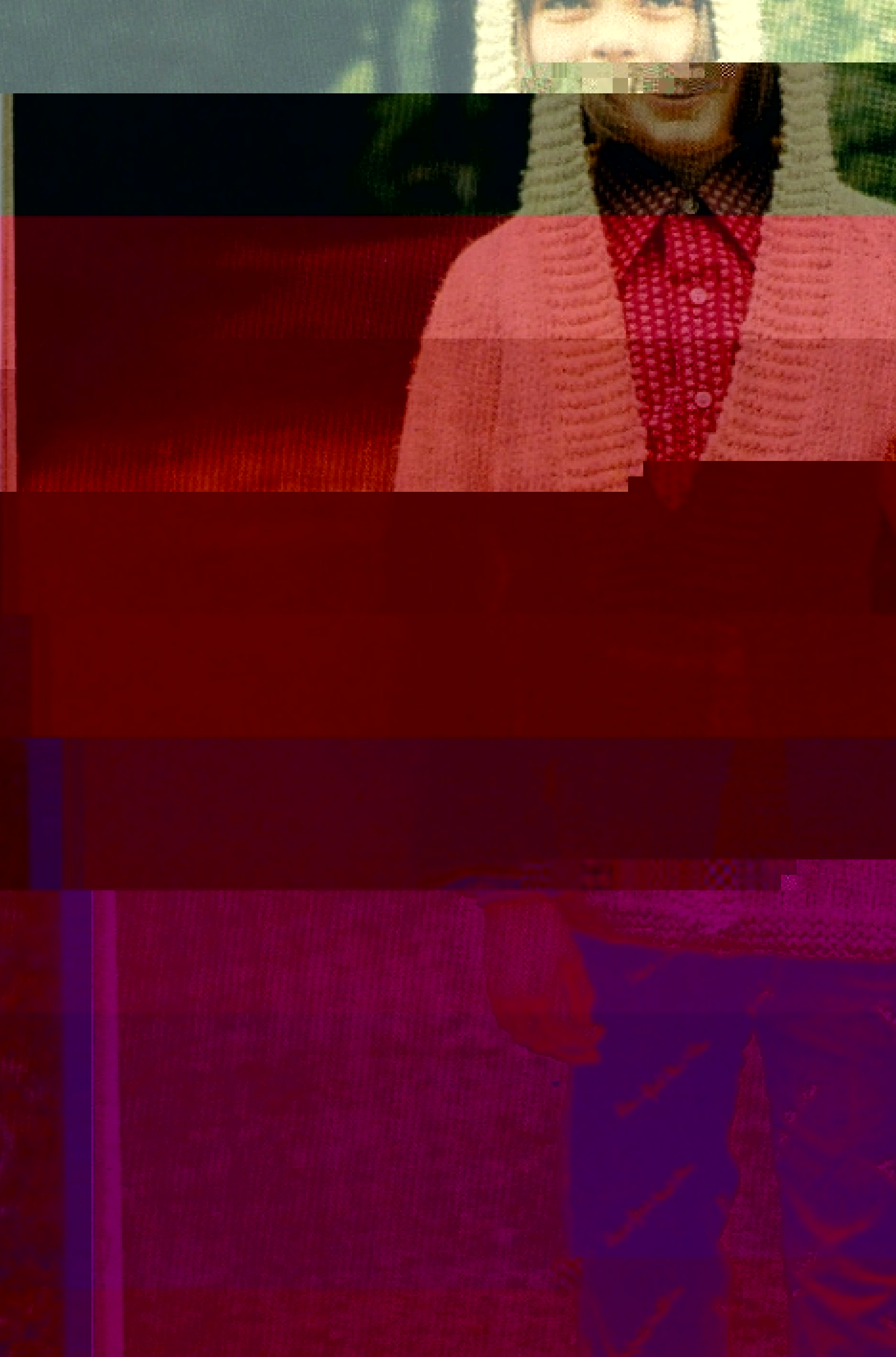
In my mapping activity, I identified a number of existing products and services that are already used by designers to create certain relatively standardized products (such as conventionally designed sweaters, or custom-coloured fabrics). These services are relatively accessible and affordable, so introducing Knitout and whole-garment knitting techniques to these existing practices runs the risk of complicating them without adding significant novelty.

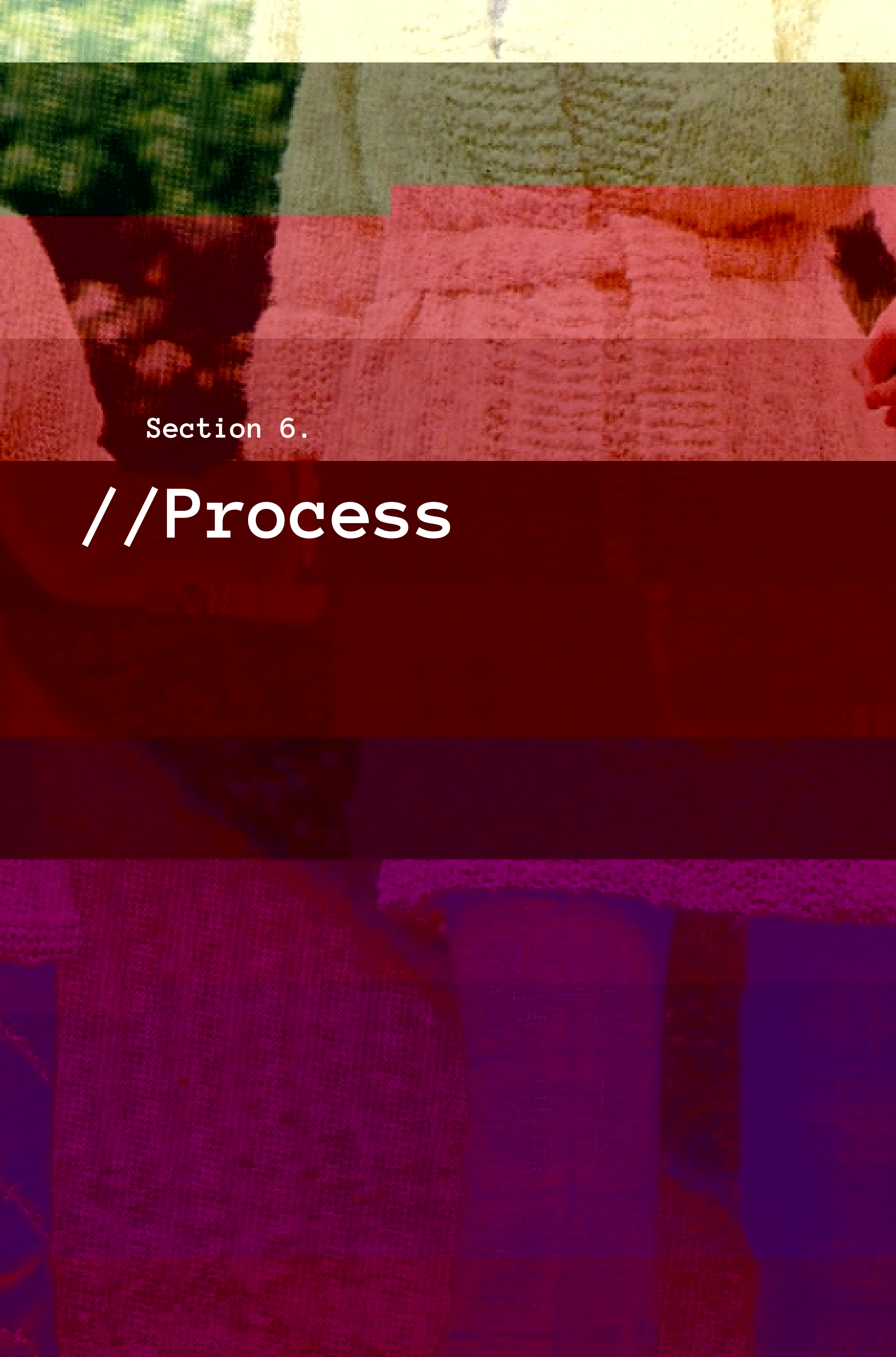
However, I identified a number of designers, artists, and makers in my horizon scan who are using knits and technology in innovative ways (see **State of the Art: Other Brands**, and **State of the Art: Artists**). The inventiveness of creators such as these suggest that many standard processes of knitting fall short of servicing the wide range of projects makers envision. Though whole-garment knitting isn't the solution for all knit-based creation, the vision of an open-source way of creating knits through technology may align with many makers' desire for flexible and experimental creation methods.

I was ultimately unable to determine a single, specific user group to envision as the most likely potential users for Hack 1 Knit 2 (see **Appendix B** for more information on my reasoning). This was, in part, due to the fact that I determined that most use cases for Knitout are characterized by experimental or non-standard qualities.

As such, the techniques I explored and documented (see **Experiments**) represent general techniques that could be used in a variety of different disciplines.

I've made the choice to focus on potential users employed outside of mass-market industries. Though technicians and designers working in large companies could potentially benefit from more accessible software, these businesses may be more financially able to support training for employees, meaning a well-documented alternative to official software options would not add as much value as it would for independently employed designers or hobbyists. Similarly, mass-market knitwear companies may have ties with knitting machine manufacturers, which could make alternative methods that are critical of how they claim and enforce intellectual property problematic.





Section 6.

# //Process

# Process

For roughly the first month of the semester, I didn't have access to the SDS-ONE APEX3 software suite. I couldn't test my code to see if it compiled error-free knittable patterns.

1 Jenny Underwood, "The design of 3D shape knitted preforms," (PhD diss., RMIT, 2009), 62–137.

A month and a half after that, I was given permission to use the SWG061N whole-garment knitting machine. Though I understand the reasoning between having formal policies in place to access specialized equipment, to say I was anxious for those first months of the semester would be an understatement. There was a very real chance that my code would produce nothing of use.

Nonetheless, I developed methods of producing purposeful code to keep my project moving forward as I waited for paperwork to process and keys to be ordered. Below are some of the key resources I relied on throughout my project.

My practice-based research was later cut short when the machine started experiencing issues towards the end of April. It wasn't repaired before the end of the semester.

## //Key Information Sources

### /*The Carnegie Mellon Textiles Lab*/

The Carnegie Mellon Textiles Lab, who created Knitout, have posted a handful of code snippets in their Github repository. These snippets demonstrate how to recreate different knitting techniques. At the time of writing, these samples all relate to creating two-dimensional knit stitches, such as waffle knits or entrelac, so I had to look elsewhere to understand how to perform shaping or create three dimensional forms. Nonetheless, these files were essential to understanding how to write Knitout.

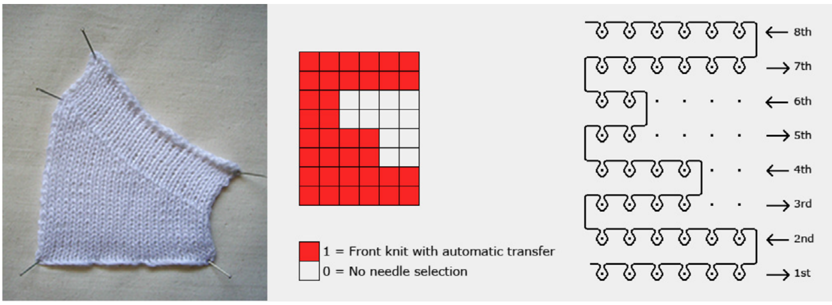
Jim McCann, leader of the Carnegie Mellon Textiles Lab, also answered some questions of mine via email related to adapting some of their code, which was written to work with a larger SWG-N2 class knitting machine, to work with KHiO's smaller SWG-N class machine.

## /*Shape Lexicon*/

I have discussed Jenny Underwood's PhD, "The Design of 3D Shape Preforms," earlier in this report.[1] Not only does Underwood do an excellent job identifying some of the challenges designers face learning whole-garment knitting, she also provides a practical response to some of these challenges in the form of the Shape Lexicon.

The Shape Lexicon is a resource that demonstrates how one would make a particular shape in KnitPaint. It is, to my knowledge, the only document like it in the research sphere.

For example, consider Underwood's diagram demonstrating how to knit a shape composed of angled segments which combine to create a curve (figure 6.1). This pattern uses a knit command similar to one available in Knitout, so, with the carriage direction provided on the right, I can easily adapt this principle into Knitout.




**6.1. Jenny Underwood, Figure 4.1 from "The design of 3D shape knitted preforms," (PhD diss., RMIT, 2009), 64.**

Other techniques require a bit more work to translate. The challenge comes from the fact that KnitPaint allows users to pick from over 200 different commands in order to design a pattern. Knitout uses just 16. It is possible, though, to use these 16 stitches in combinations that can replicate most if not all of the functionality of Knitout.

I was able to adapt much of her work on flat knitting techniques without much issue. However, Underwood's images explaining 3D knitting techniques are more complex to translate into Knitout. They make use of a selection of whole-garment-specific knitting commands that are composed of more complex sequences of commands and are sometimes visually more abstract. Though I didn't have as much luck translating these snippets, Underwood's description of the theory behind each technique was enough to allow me to develop my own procedures for developing Knitout code for some whole-garment objects.

### /*KHiO Support*/

KHiO's workshop manager, Dagfinn Skoglund, was responsible for demonstrating how to use the knitting machine, including how to change yarns, load files, change settings, and basic troubleshooting.

Knit designer and PhD fellow Camilla Bruerberg also provided occassional feedback that helped me to troubleshoot issues in failed experiments.

## //Steps

In order to knit, the file must go through a number of different transformations. These steps are illustrated in figure 6.2 on the following pages.

Towards the end of this report, I have included **Appendix C: Processing a Knitout-generated DAT File in SDS-ONE APEX3** and **Appendix D: Knitting on the SWG061N Knitting Machine**. These appendices are intended to act as instructions for potential users of Knitout given the limited documentation available on Shima Seiki knitting machines.

Figure 6.2. From Knitout to Knit

## Process

### Step

**1.**

### Write a Program

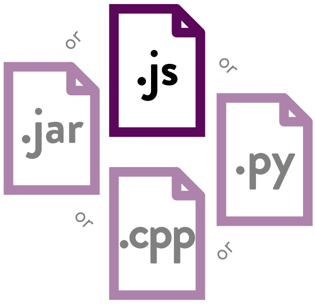
Knitout is not a programming language, but rather a file specification. Though you can write Knitout directly in any text editor, it makes more sense to create a program that writes to Knitout for you.

**2.**

### Generate Knitout File

Running your program should generate a Knitout file, designated by the file extension .k or .knitout.

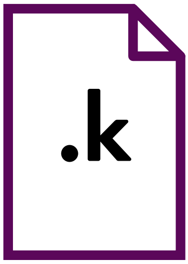
### Output of Step




### JavaScript (or Other) File

This file contains code representing instructions to build a knitted item. Its purpose is to write text to another file containing these instructions formatted according to the .knitout file specification.

I chose to use JavaScript for this step, but most programming languages could be used.




### Knitout File

This file contains a list of instructions for how the knitting machine should construct your knitted item.

When programming this file, you can insert comments, making the file largely human readable.

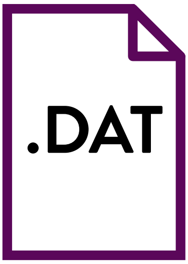
### Equipment

**Personal Computer**

# 3.

## Translate to DAT

Use the program knitout-to-dat.js from Carnegie Mellon's Github repository knitout-backend-swg to convert your file into a .DAT file.




## DAT File

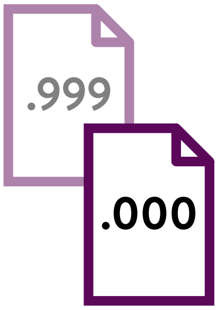
When opened in KnitPaint, or by The Carnegie Mellon Textiles Lab's own DAT Viewer program,  A DAT file is visualized as a colourful grid.

The file is encoded, meaning that when opened in a text editor, it is not human readable.

# 4.

## Compile to .000 and .999

Copy the .DAT file onto the SDS-ONE APEX3 computer. Double-click it to open it in KnitPaint. Run the Automatic Process function (see **Appendix C**) to generate a .000 file, and optionally a .999 file.




## 000 and 999 Files

A 000 file represents the majority of the information of your knitted object, recompiled so that the knitting machine can interpret it.

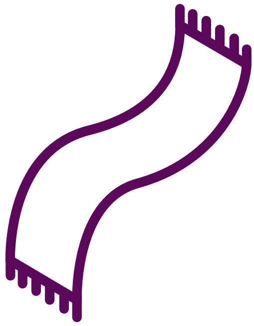
A 999 file contains options, such as the length of yarn used in each stitch. If a 999 file isn't generated, the user can opt to change settings on the knitting machine.

## SDS-ONE APEX3

# 5.

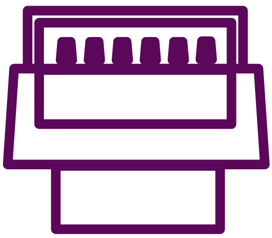
## Knit on Machine

Copy the .000 and, if created, .999 file onto a USB drive, and insert it into the machine. Follow the steps in **Appendix D** to knit an item.



## A Knitted Item

The object you designed in step 1. With a few knots to tie off loose ends, it's ready to go!



## Knitting Machine

Section 7.

# //Experiments

# Experiments

These images represent different forms I created on the whole-garment knitting maching using program-ming and knitout. The categories are somewhat loosely defined, as I devised each experiment based on the limited documentation available, and my own knowledge, which grew with each sample.

## //Flat Stitches

These patterns consist of different types of flat stitches, as well as experimentation with changing colours.


Figure 7.1. Flat knitted samples created using Knitout.

## //Shaping

These experiments explore ways of changing the shape of flat knitted samples, but introducing or reducing stitches, or by adding holes.

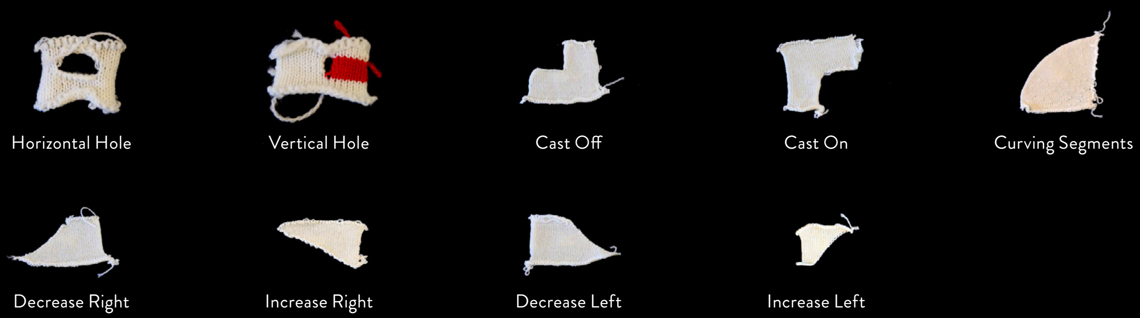



Figure 7.2. 2D Shaped knitted samples created using Knitout.

## //3D Forms

These experiments include ways of creating, shaping, and colouring tubular forms, as well as other techniques involved in changing a sample's 3D form, such as techniques that involve varying row height (i.e., short rows and held stitches).

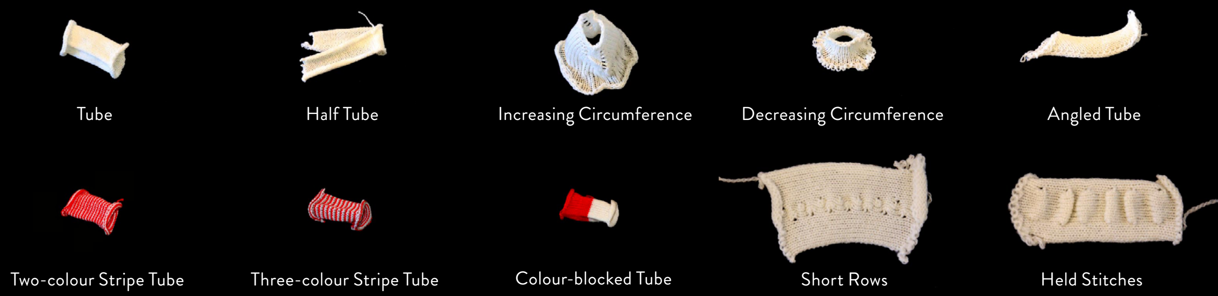



Figure 7.3. 3D knitted samples created using Knitout.

## //Other

These techniques explore generative design, randomness, and image processing as design techniques.

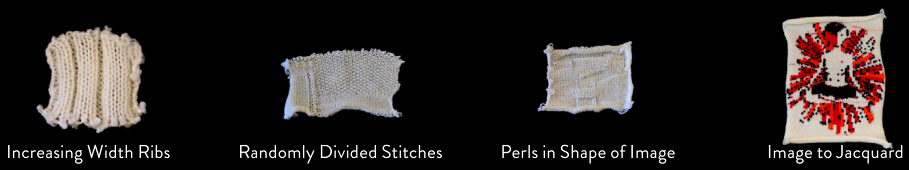



Figure 7.4. Knitted samples experimenting with generative design and other themes associated with creative programming created using Knitout.

# //Blog Documentation

In order to address my goal of lessening the learning curve for others interested in exploring whole-garment knitting technology, I published all the source code for my experiments on my Github page (e.g., see https://github.com/jessp/k-code-tests) under an MIT license. An MIT license is a very flexible license often used for software that allows a user to use and modify the code with minimal restrictions.

I also published my experiments to a blog, located on the web at https://jessp.github.io/kcodeblog. This interface is intended to be more visual and provides some organization in case visitors are looking to replicate a specific technique. The image below shows how each experiment page is structured.

I opted to include minimal mention of working with Shima Seiki machines specifically in my blog, to limit the risk of having the information taken down due to a copyright claim.

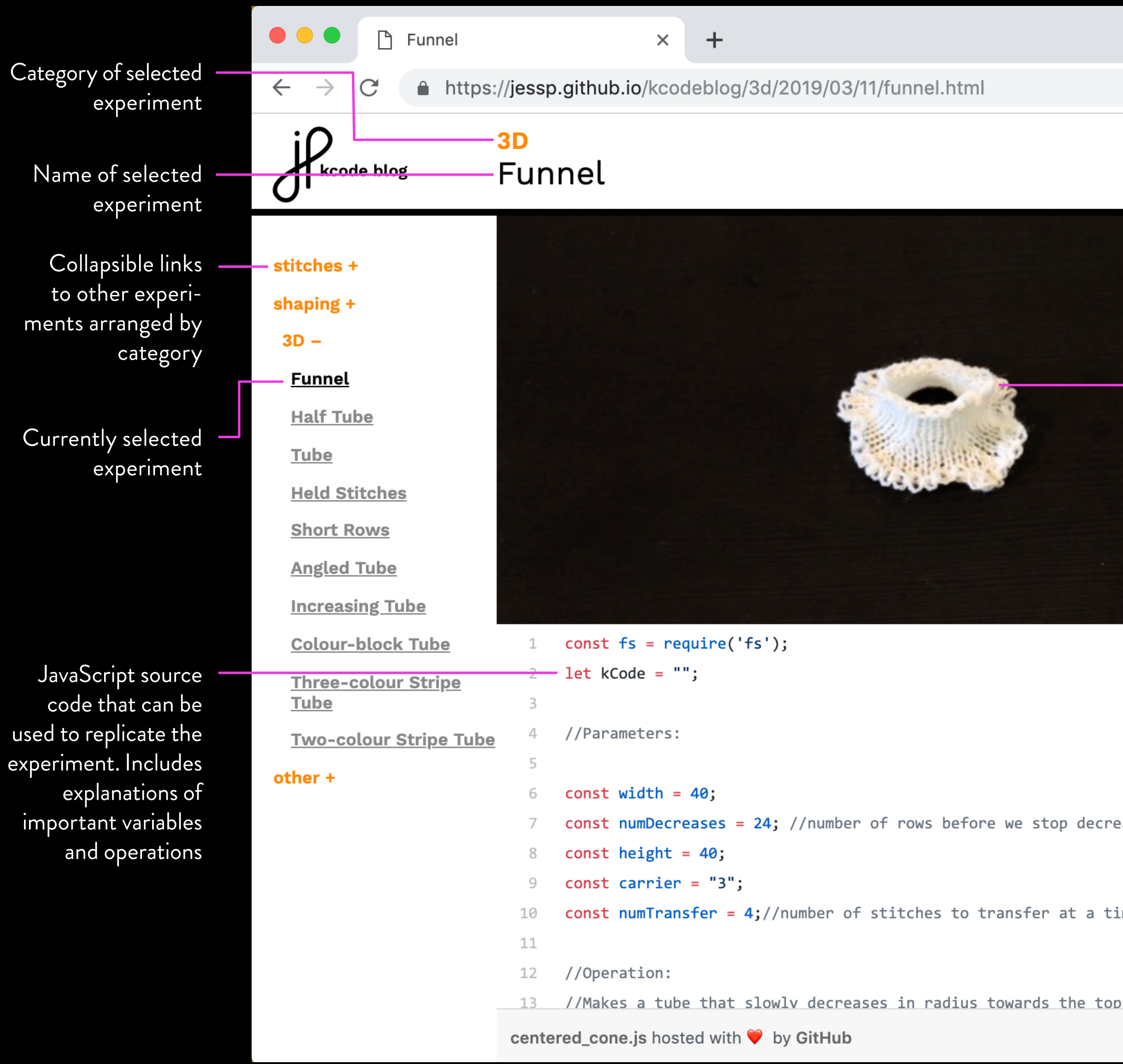



Figure 7.5. Screenshot of “kcode blog”: my website that includes source code and images describing how to replicate different Knitout techniques.

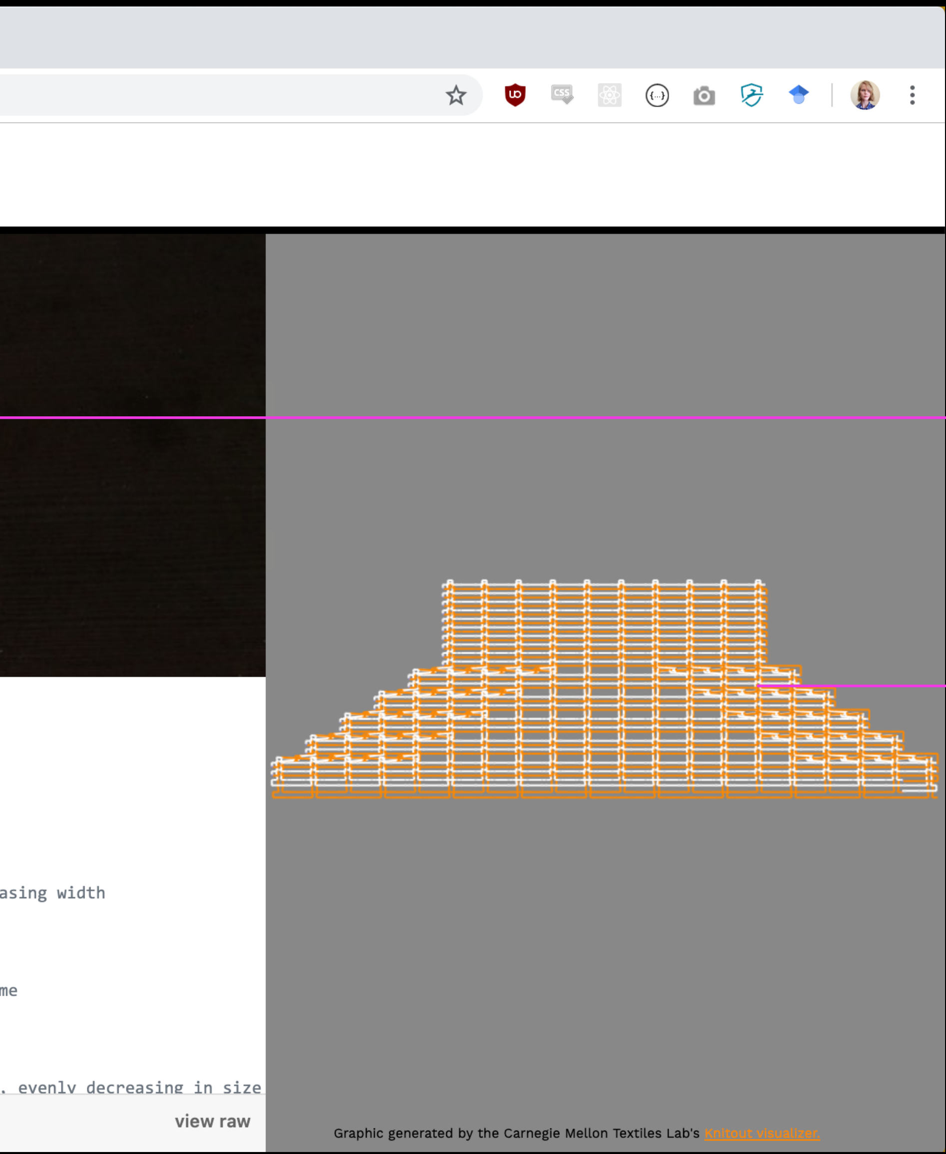



Photo of knitted experiment, demonstrating intended output

Visualization of the Knitout code using Carnegie Mellon Textiles Lab's Knitout Visualizer, reinforcing the link to the Knitout project

Section 8.

# //Key Principles of Whole-garment Knitting

# Key Principles of Whole-garment Knitting

In contrast to my blog, which documents the source code to make each object, this section addresses some practical, tactile guidelines I discovered while experimenting. I consider these to be some of the more important lessons to keep in mind when conceptualizing how to make a piece.

## //The Machine

The SWG061N is a smaller model of whole-garment knitting machine created by Shima Seiki. The photos below in figure 8.1 were included to highlight various pieces of hardware discussed in this and other sections.

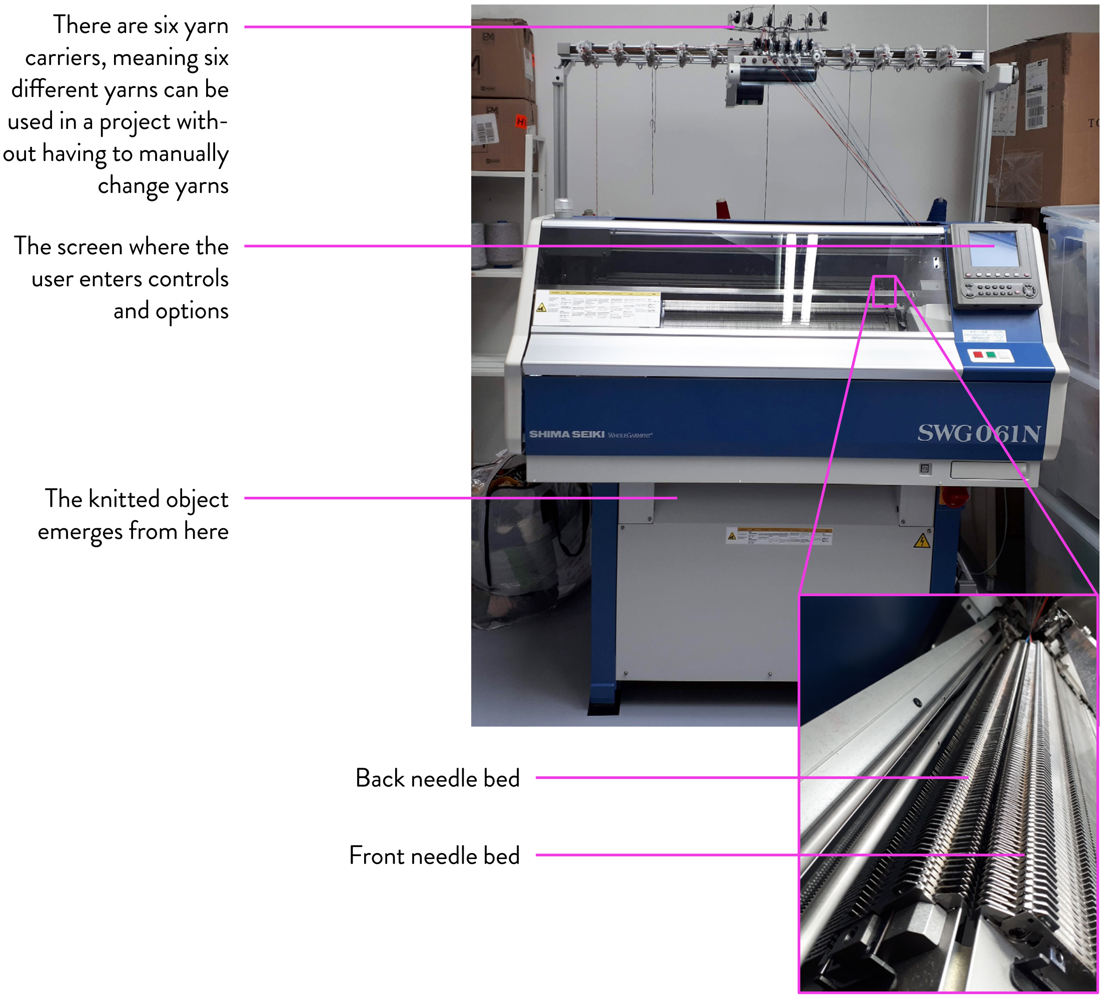



**Figure 8.1. Key hardware components of the SWG061N whole-garment knitting machine**

# //The Importance of Direction

Knitting machines can perform knitting operations going torwards the left or the right. Direction is an argument used in most commands in Knitout. For most flat knitted objects, knitters should aim to alternate between a row of stitches foing towards the right with a row of stitches going towards the left (figure 8.2). Doing otherwise results in the knitted item coming out in two pieces, connected by a long piece of yarn (figure 8.3).

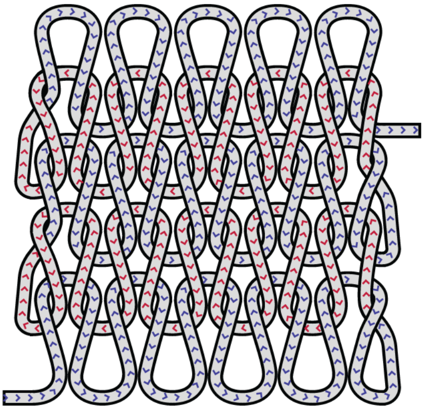


Figure 8.2. Correctly alternating directions.

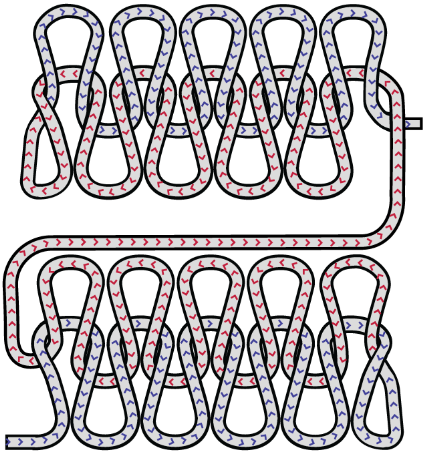


Figure 8.3. Incorrectly alternating directions, resulting in disconnected pieces.

Direction also plays a key role in creating whole-garment knitted pieces. By changing direction and switching between knitting on the front and back needle bed, the user can create a range of different shapes, of particular use in garment creation, as shown in figures 8.4 - 8.6.

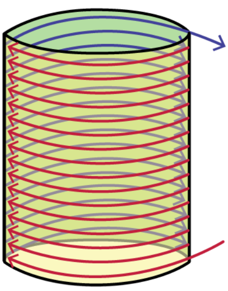


Figure 8.4. A tube formed by knitting to the left on the front bed, and to the right on the back bed all with the same yarn.

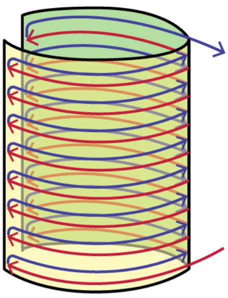


Figure 8.5. A half-tube formed by alternating left and right with the same yarn on the back and front bed.

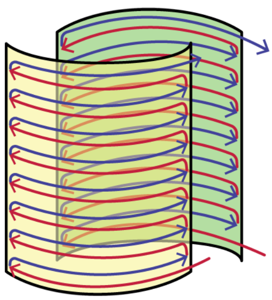


Figure 8.6. Two disconnected fabric swatches formed by alternating left and right with a different yarn on the front and back beds.

# //Transferring

Users can transfer yarn between the back needle bed and the front. Yarn can only be transferred between two needles directly across from each other. By moving the back bed back and forth, in an operation called racking, the user can change which needles are viable for transferring to or from (figures 8.7 - 8.8).

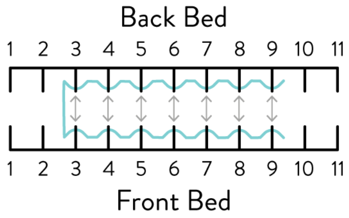


**Figure 8.7. Transfers possible at racking position 0.**

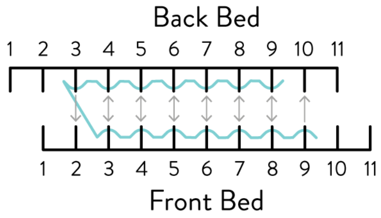


**Figure 8.8. Transfers possible at racking position -1.**

1 Knitters will be aware that we aren't knitting in true half gauge using this method, but an approximation of it.

Transferring is used in a variety of flat shaping techniques, such as casting off and decreasing fabric width. To transfer and shape effectively in whole-garment knitting, however, the user must knit on every other needle, to ensure there are available needles to transfer to when both needle beds are in use. This arrangement is known as knitting half-gauge (figures 8.9 - 8.10).[1]

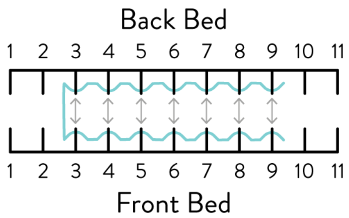


**Figure 8.9. Knitting whole gauge.**

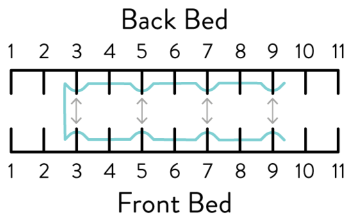


**Figure 8.10. Knitting half-gauge.**

Even given this explanation, it can be difficult to envision how transferring can be used to give shape to a knitted tube. The images on the facing page (figures 8.11 - 8.17) illustrate how to begin to decrease the circumference of a tube shape.

# //Transferring Procedure for Whole-garment Knitting

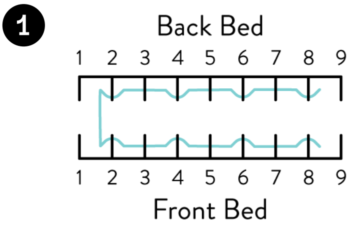



Figure 8.11. Knitting a tube half-gauge at racking 0.

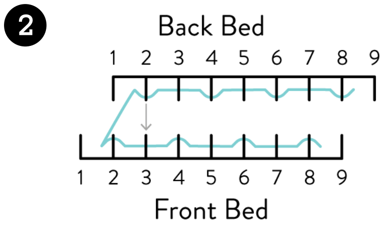



Figure 8.12. Set racking position to 1.

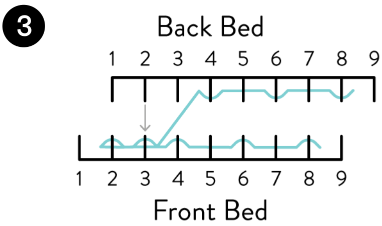



Figure 8.13. Transfer yarn on b2 to f3.

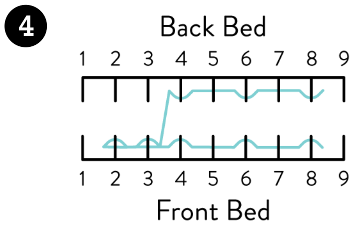



Figure 8.14. Set racking position to 0.

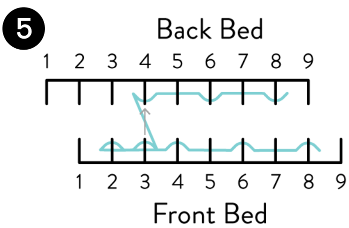



Figure 8.15. Set racking position to -1.

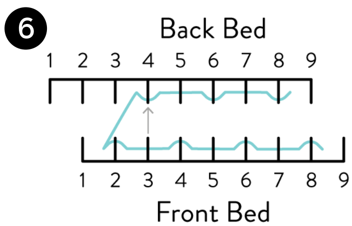



Figure 8.16. Transfer yarn on f3 to b4.

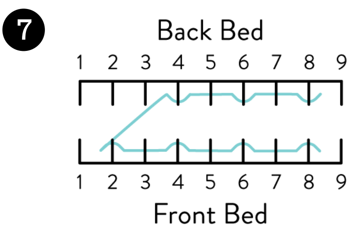



Figure 8.17. Rack the back bed back to the 0 position. Note that it holds only three loops of yarn rather than the four it started with.

Section 9.

# //Sample Objects

# Weather Data Objects

Few general-purpose graphics software programs offer the ability to create visuals based on data. I was intrigued by how data is used as input for different forms of rapid prototyping, such as how digital scans are used as input for 3D printing.

With this in mind, I wanted to explore how Knitout could be used to create forms based on data through code.

I created these data sculptures based on weather data from different Canadian cities (figure 9.1). Each ring represents a year of weather from a given city. I chose the ring shape to represent the cyclical nature of weather.

These objects are not intended to be functional in any way, but meant to showcase the capabilities made possible by combining whole-garment knitting and coding.

**Figure 9.1. Data sculptures based on Canadian weather data from different cities.**

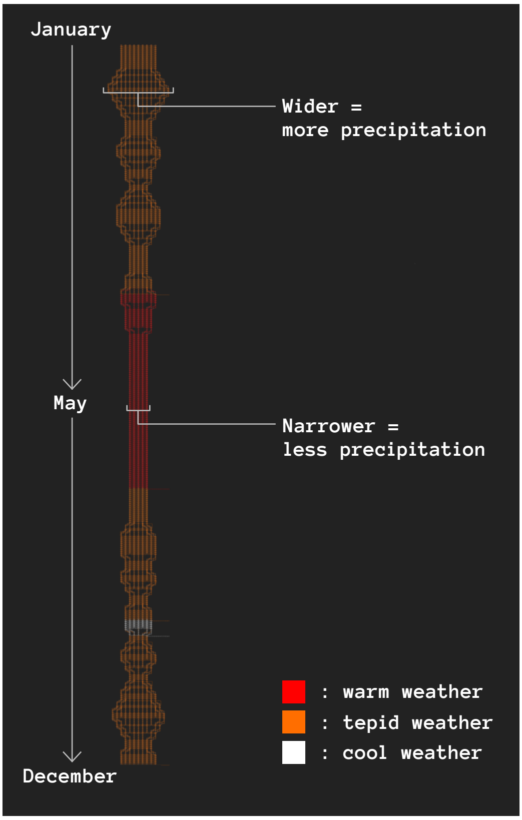



Figure 9.2. Vancouver weather sculpture rendered in Knitout file visualizer, annotations are my own.

The circumference of the edge of the ring changes to reflect the precipitation experienced in the given city in a given week of the year, with a wider segment representing more precipitation. The colour of each segment represents the warmth of the week. Figures 9.2 - 9.5 show the effect of this using renderings made with Knitout's file visualizer, prior to when the rings are joined at the ends with a seam.[1]

1 "Knitout Live Visualizer" (Github code repository), last updated April 23, 2019, https://github.com/textiles-lab/knitout-live-visualizer.

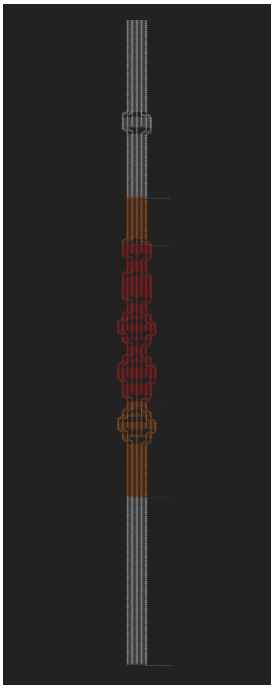


Figure 9.3. Yellow Knife weather sculpture rendered in Knitout file visualizer.

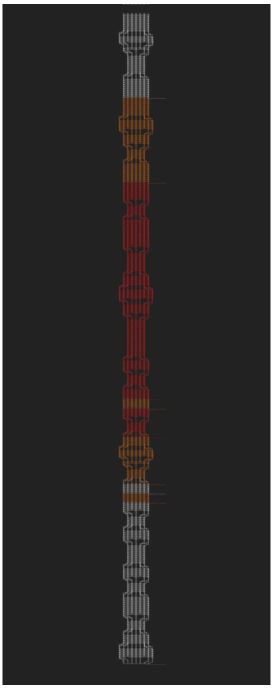


Figure 9.4. Montreal weather sculpture rendered in Knitout file visualizer.

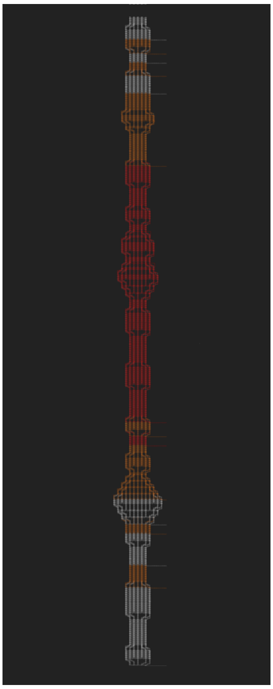


Figure 9.5. Toronto weather sculpture rendered in Knitout file visualizer.

# Garments

Given that whole-garment knitting technology was developed with clothing production in mind, it was important for me to demonstrate that it is possible to create functional garments with Knitout.

Figure 9.2. Top: first iteration miniature shirt made with three yarn carriers. Bottom: second iterature shirt made with one yarn carrier and improved technique for joining sleeves.

Given the small size of the machine I'm using, I was limited in terms of the items I could create.

## //Miniature Shirt

I designed a small sweater based on a few simple techniques, all of which I explored during my sample-making session. It consists of three tubes making up the body and arms, which are then joined into a larger tube for the shoulders, which then decreases in width through a process of repeatedly transferring stitches closer to the center of the tube in order to form the neck (see figure 9.2).

Figure 9.3. A sweater knitted to the proportions of a small figurine. Photo by Petter Vilberg, April 20, 2019.

The shirt's dimensions are easy to alter due to the garment's simple construction. This speaks to the theme of mass customization, particularly for sizing. This theme has been explored by many major clothing manufacturers, some of which are discussed in **State of the Art: Brands Working with Whole-garment Technology** and **State of the Art: Other Brands**. Figure 9.3 shows a shirt that has been custom made to specifically fit a figurine of unusual proportions.

## //Sleeveless Shirt

Figure 9.4. Sleeveless shirt.

I also decided to create something wearable to further enforce the functionality of the pieces created. I opted for a sleeveless design, given that the machine isn't large enough for a full-size shirt with sleeves (see figure 9.4).

The shirt features a side slit, a roll neck, and stripes to add visual interest. In order to create this shirt, I drew on my experiments with connected, semi-connected, and unconnected tubes for the various parts of the shirt. Figure 9.5 shows the shirt being worn.

Figure 9.5. The sleeveless shirt in use.


E
D
K
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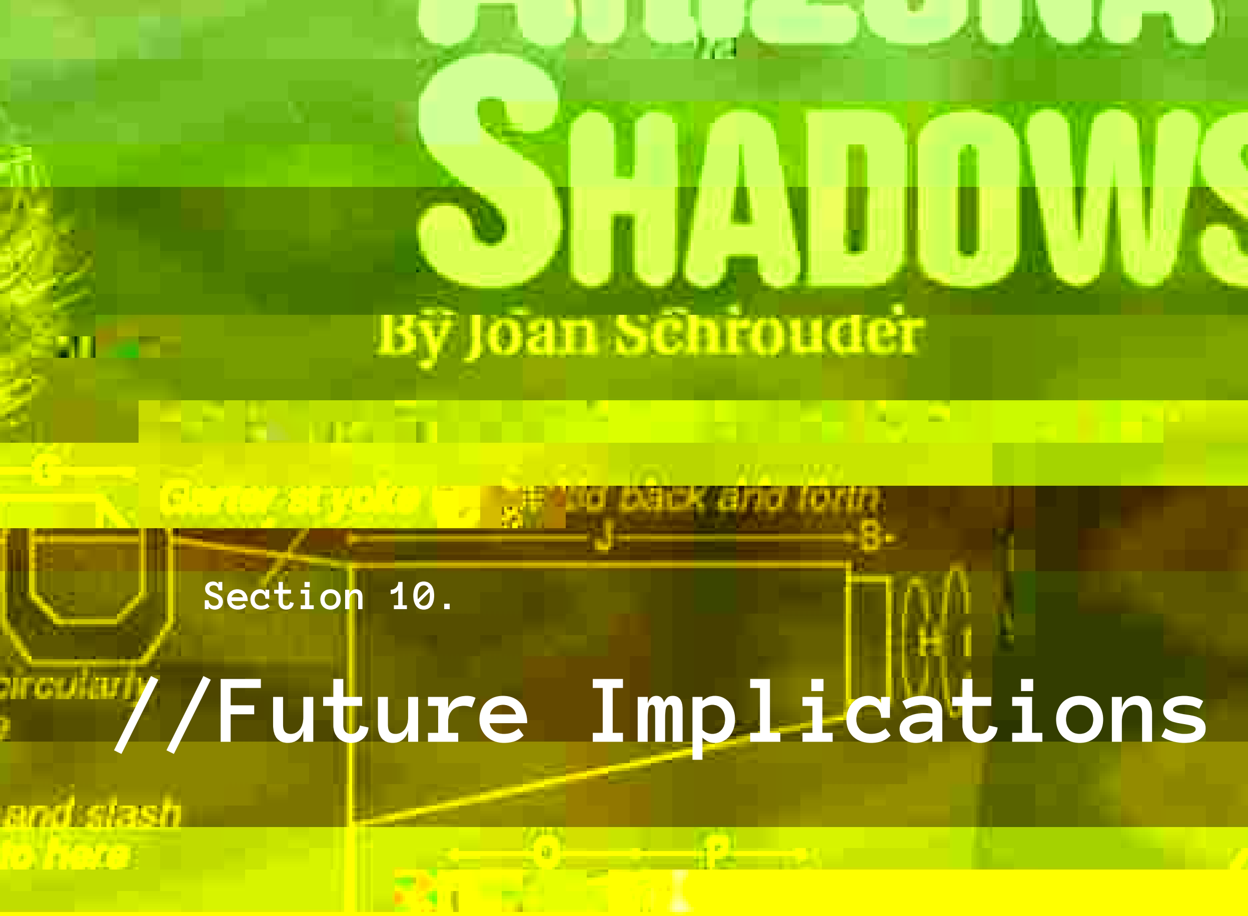
Stitch
C




Section 10.

# //Future Implications

# Future Implications

## //The Importance of Knits

It can be hard to abandon the image of knitting as purely a leisure activity. Though I don't want to speak down to the importance of knitting as a hobby, I would be remiss if I didn't speak to the broader possibilities of knitting.

In this section, I discuss the possible implications of a near future where whole-garment technology is available to designers outside of the mass-market industry, and some items that could be created in this reality.

## //The Circumstances

These scenarios take place only a few years in the future, where projects like mine, and the work of the Carnegie Mellon Textiles Lab, have increased public interest in whole-garment knitting.

This interest, and pressure from the popularity of competing products like Kniterate, has led Shima Seiki to officially support Knitout in addition to their proprietary software.

Makerspaces and educational institutions purchase whole-garment knitting machines in greater number. Though they are mostly older and lower-end machines, their availability is enough to capture the interest of hackers, makers, and designers of all sorts from all over the world.

The userbase is small but enthusiastic. Much of their activity centres around h1k2.org (a currently fictional website), a forum where users post links to their projects, and ask for help as they learn Knitout.

The next pages in this section describe just some of these designers and their projects.

## //The Designers

The designers profiled in these scenarios include creators from across discplines. Many might not even identify as designers, but rather as makers, artists or scholars. This relates back to my decision in **Needs Assessment: Summary** to focus on general purpose knitting techniques, that could be used by creators in a variety of different ways.

## //Criteria for Inclusion

I developed these scenarios by brainstorming ways whole-garment knitting could be used in different fields. I decided to focus on the ones included based on how well they represented a diversity of applications, and how plausible these applications seemed.

## //Eco Pets

Ash designs knitted plush toys in Knitout using an open-source graphical user interface under the brand name "Eco Pets." They use organic, fair trade wool and has their toys manufactured at a local makerspace, lessening the chance that the toys will be made in a place with poor labour practices.

Ash originally only sold Eco Pets at local craft fairs, but recently, through h1k2.org, discovered a community of like-minded customers eager to purchase their designs. Ash now sells their creation in an online store on Etsy.com, in addition to sharing their sourcefiles for other designers who would rather knit their own Eco Pets.

## //Refurbished, Refreshed

“Refurbished, Refreshed” is a capsule furniture collection by product designer Lars and interior decorator Linda. The two of them source used furniture from antique markets and thrift stores. They then replace any upholstery with custom covers made using Knitout.

Many of their customers come from Linda’s work in interior design. Sometimes, it’s much easier to make that perfect living room focal point than to buy it from a store.

## //Cozy Consequences

Jamie and Glenn self-identify as hackers. They live on opposite sides of the world.

Both of them are participating in the "Cozy Consequences" project hosted by h1k2.org to design a scarf. The project is inspired by the exquisite corpse party game, with each person contributing a segment without knowing the entirety of what the previous maker created.

At the end, the source code will be released so that all participants can create a sample of their shared design.

# //History You Can Feel

Ms. Fatima is a primary school teacher. With support from her schoolboard, and the cooperation of technicians at her local museum's makerspace, Ms. Fatima has spearheaded the "History You Can Feel" program.

In "History You Can Feel," educators work with technicians to select textile-based artworks to replicate with Knitout. These might be sourced through images found on the internet, or from scanned objects in the museum's collection. These replicated artificacts become the property of the schoolboard, and can be booked by educators to bring into the classroom for students to interact with.

Ms. Fatima was inspired by scholars like Sarah Dudley, who argue that seeing an object is only one way to experience it, and that other senses may be necessary to form a stronger, more emotional impact.[1]

1 Sandra H. Dudley, "Museum materialities: Objects, sense and feeling," Museum Materialities, Routledge, 2013.

## //PEARS Research

In Southern Ontario, a hospital research lab is developing a unique take on a medical device called a PEARS (a personalized external aortic root support) using whole-garment knitting technology and Knitout.

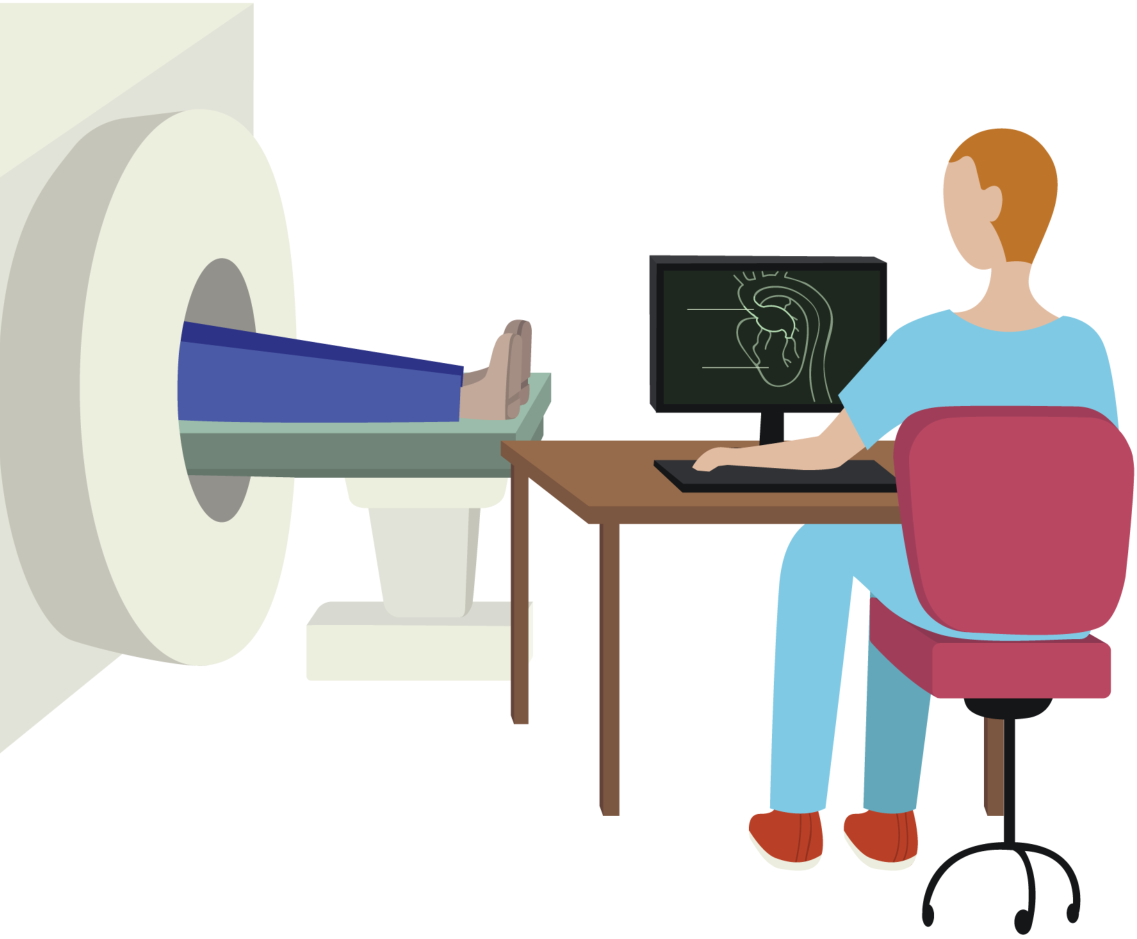
PEARS devices help patients with Marfan syndrome, who can have life-threatening heart issues, by supporting the aortic root wall, which is prone to stretching and even splitting if untreated.[2]

In the past, PEARS have been made using 3D printing technology to make a mold of a person's aortic root based on CT scans. Then a special textile mesh is formed around the mold, which is then fitted around the patient's aortic root.[3]

These researchers believe that, by developing software to directly knit a mesh from a whole-garment knitting machine, they can cut down on the manufacturing time and necessary materials.

2 Treasure, Tom et al. "Personalised external aortic root support (PEARS) in Marfan syndrome: analysis of 1-9 year outcomes by intention-to-treat in a cohort of the first 30 consecutive patients to receive a novel tissue and valve-conserving procedure, compared with the published results of aortic root replacement." Heart 100, no. 12 (2014): 969-975.

3 Ibid.



## //Artificial Muscles

A research group at a technical university in Germany are investigating how custom knit components could be used in creating artificial muscles. By coating yarn in electroactive agents and applying a current to it, the textile will expand in a different way depending on how it was knitted.[4, 5] The stretch of fabric makes it an ideal option for a range of applications, such as for prosthetics, specialized robots, and assistive technology.[6]

This research group has been experimenting with whole-garment knitting as a way of getting precise control over the structure of the artificial muscle, and manipulating its shape.

4 Malin Otmani, "Knitting and weaving artificial muscles," Nordic Life Science News, published January 26, 2017, https://nordiclifescience.org/knitting-weaving-artificial-muscles.

5 Ali Maziz, Alessandro Concas, Alexandre Khaldi, Jonas Stålhand, Nils-Krister Persson, and Edwin WH Jager. "Knitting and weaving artificial muscles." Science advances 3, no. 1 (2017): e1600327.

6 Ibid.

## ...maïeu...

**...oose according to ...te and to what you ...have, but both choices ...pting.**

...g sleeves, wide cuffs ...is cardigan its unique ...itted in **stockinette ...d edged in ribbing.** ...eight yarn and a few ...of Novelty yarn.

...The long jacket and hat ...anced by motifs ...ed in **pineapple stitch.** ...g Worsted Weight.

...**2** - In shades of brown, ...dark brown to ecru, this ...eu of shading-off colors ...to this ensemble of long ...gan, hat and scarf, its ...et elegance. Knitted in ...**nette stitch, moss stitch ...bbing.** Knitting ...sted Weight yarn.

Section 11.

# //Conclusions

# Conclusions

## //Shima Seiki and Intellectual Property, Revisited

Throughout this report, I have made numerous claims that Shima Seiki's unintuitive interface, lack of support for alternative design methods, and lack of learning resources may stem from their desire to prevent competition from other businesses, and to preserve the portion of their revenue fed by providing support and training session. This could be read as a criticism of their enforcement of intellectual property (or IP) and that's not entirely wrong.

To be clear, I am not opposed to companies protecting the intellectual property rights of their products. I am, however, critical of situations when aggressive IP enforcement limits innovation (as may be the case with the lack of official support for Knitout and other user-led design tools), or when IP enforcement limits a particular group (e.g., people outside of the mass-market fashion industry) from engaging with a new technology.

Though admittedly Shima Seiki has a more limited customer base, it's valuable to compare their business model to a company like Adobe's. Adobe publishes numerous help resources for free on their website and makes them available under a Creative Commons license.[1, 2] They offer tools like the Adobe Extension Builder that allows users to develop custom tools that can be integrated into Adobe products.[3] Perhaps most importantly, they have attempted to create a sort of community of support through forums where users and Adobe staff ask and answer questions about the product.[4] Despite, or perhaps, because of their availability to the public, Adobe remains a leader in their software field. Though Shima Seiki does have a dedicated website for users featuring forums and learning tools, access seems to be limited by the same restrictive licensing agreement as the software itself.[5, 6]

The SDS-ONE APEX3 software suite lacks community. I am not the first person to suggest that whole-garment knitting technology attempts to silo users into inflexible roles: The designer and the technician are viewed as separate species. Symbiotic, perhaps, but separate. Without the existence of a community and inadequate resources, to encounter an error in SDS-ONE APEX3 is to be stuck on an island. There is no support in the face of challenges, or praise for contributing achievement to a shared knowledge base.

1 E.g., see Adobe, "Download and install your Creative Cloud apps," accessed May 10, 2019, https://helpx.adobe.com/download-install/using/download-creative-cloud-apps.html.

2 Creative Commons licenses are special types of copyright licenses designed to encourage sharing of materials.

3 Adobe, "Adobe Extensions Builder", accessed May 10, 2019, https://www.adobe.com/products/adobe-extension-builder.html.

4 E.g., see daniellzy [username], "Error initializing Creative Cloud Desktop App" [forum], Adobe Forums, published Jun 5, 2018, https://forums.adobe.com/thread/2499040.

5 Shima Seiki, "What 'Users' Site' can provide?," accessed May 12, 2019, https://www.shimaseiki.com/user/kiyaku/index.php?-cas=user.

6 I emailed the company May 12, 2019, to clarify to clarify the definition of "users" for their Users' Site, but have not received a response as of May 20, 2019.

## //Reflections

My semester of practice-based research supported many of the claims reported by other scholars on whole-garment knitting. Firstly, I experienced first-hand the frustration of navigating a technology bereft of an intuitive user interface or straight-forward learning resources. But, more importantly, I also feel more confident than ever in the potential for whole-garment knitting as a tool for designers.

My goals for this project were to:

1. Lessen the learning gap to others interested in exploring whole-garment technology
2. Make a case for how whole-garment technology could be incorporated into more makers' practices

In service of this first goal, I created a blog that documented the code required for replicating many of my experiments. I also included some insights on using and operating Shima Seiki equipment in this report that may be of interest to future users. These solutions are far from complete, as discussed below, but given the limited public resources available before my work, they indicate a small but significant step forward.

The success of my second goal is more difficult to determine because it speaks to something far more personal and less concrete: inspiration. In the interest of creating items that appeal to different forms of making well-suited to whole-garment knitting, I explored garment creation, and data visualization as described in the **Sample Objects** section. The experiments profiled in **Experiments** represent simple techniques already used in knitting that can be combined and developed into larger projects. In **Future Implications**, I described a range of different, but plausible, projects that could exist if whole-garment knitting technology were more available to the masses. Though my work demonstrates that it is possible for a designer to use open-source techniques to create whole-garment knits with minimal use of Shima Seiki's proprietary tools, It remains to be seen if my work has or will inspire others to take up whole-garment knitting via Knitout or otherwise.

## //Next Steps

Ultimately, I cannot be the main agent for change in making whole-garment knitting more accessible to designers. Knitting machine manufacturers and software designers must take some kind of action that either allows for more flexible software licensing alongside releasing a more intuitive interface, or decide to officially support user-initiated ways of making, like Knitout.

However, just as I set out to make a case for how whole-garment knitting could be incorporated into more makers' practices, my project could be seen as part of a movement to make a case to knitting machine *manufacturers* to change their practices in order to allow access to more types of creators. There are numerous activities that could be undertaken under this missive, many of which I didn't have the opportunity to discuss in this report in detail.

One approach might be to look at various factors, including financial models, that would need to be considered by small companies, makerspaces, and educational institutions if they wanted to purchase a whole-garment knitting machine.

As a more grassroots approach, the amount of literature on whole-garment knitting and Knitout is still limited. Though I created a blog, the text there is incomplete in it's limited collection of posts and lack of instructions for problem-solving hardware-related issues. It's also difficult to know if users will be able to find the website. Additional web resources, such as forums, instructional websites, or videos could be produced to educate potential users. Print publications may also be useful in the digital age where popular websites may be required to remove content based on a copyright claim (regardless of whether the purpose of the content constitutes fair use), leaving it up to the creator to repeal the claim.[7]

Perhaps most importantly, more users should be engaged with Knitout, in order to see how they would use it, and how to best teach it, in order to better understand its potential. As my project required a long period of personal exploration in order to better understand the technology, I was unable to engage with potential Knitout users in an educational capacity. Future work might involve crafting and piloting Knitout workshops for users from different backgrounds in order to gauge how, and if, they are able to use the technology.

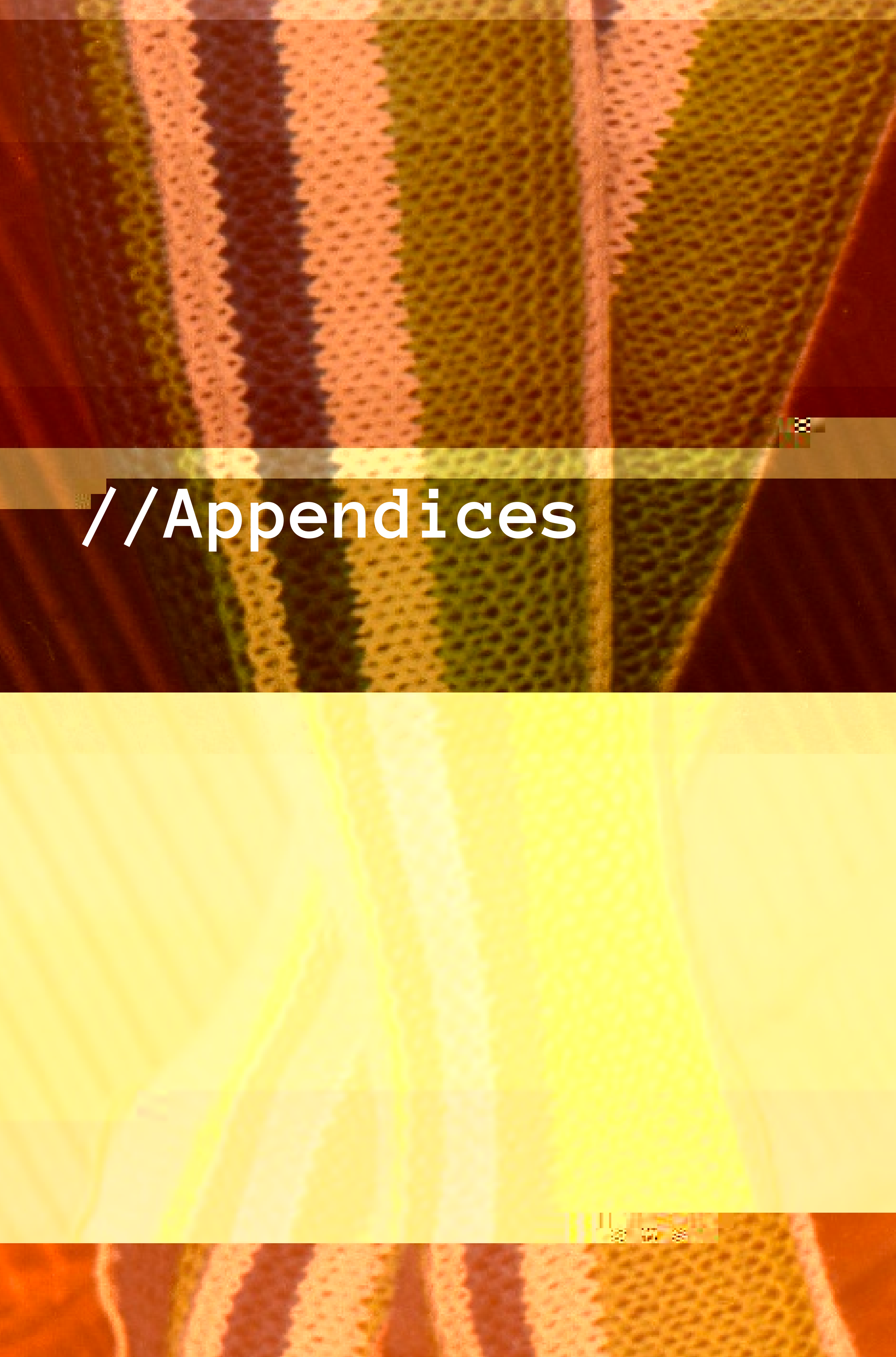
7 E.g., see YouTube's guidelines for content creators receiving copyright claims: Youtube, "Copyright strike basics", accessed May 10, 2019, https://support.google.com/youtube/answer/2814000?hl=en.

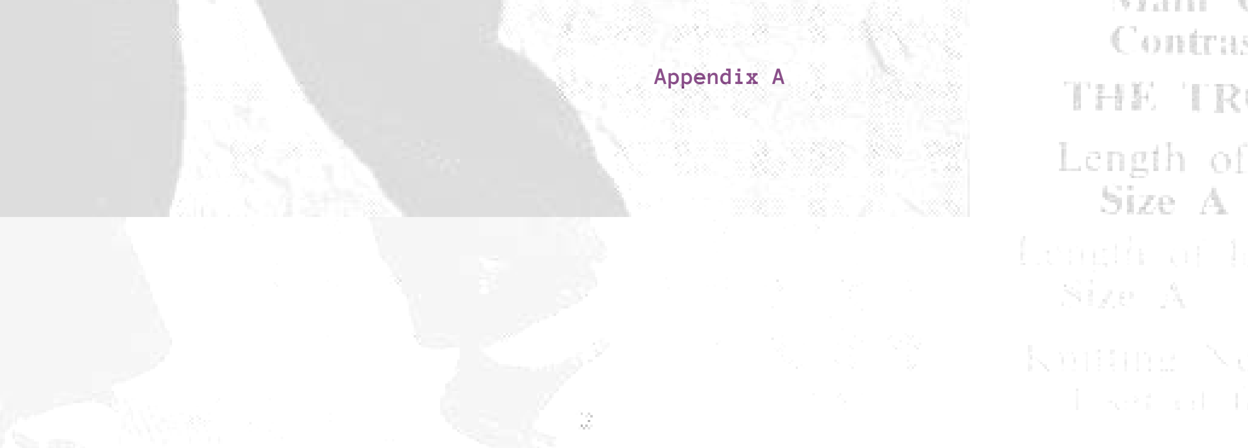
**shoulder bag which will be an elegant substitute to a purse or a tote bag! Don't deprive yourself of them for fear that you are not up to it yet. Contrary to what you may think, they are extremely easy to make.**

**72** The pinchos: - Knitted in **garter stitch,** the basic stitch.
- Their shape, very well designed, requires only a minimum of steps to follow
- Only **one whipstitched seam** is needed in the finishing
Sport weight yarn.

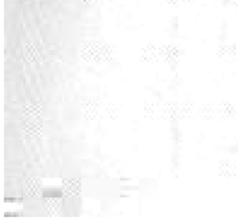
**73** The bag: Croch[illegible] **single crochet,** the basic stitch.
- Alternating colors is no problem.
Its shape, a **folded rectangle,** makes the finishing ultra simple.
Heavy weight yarn.

# //Appendices





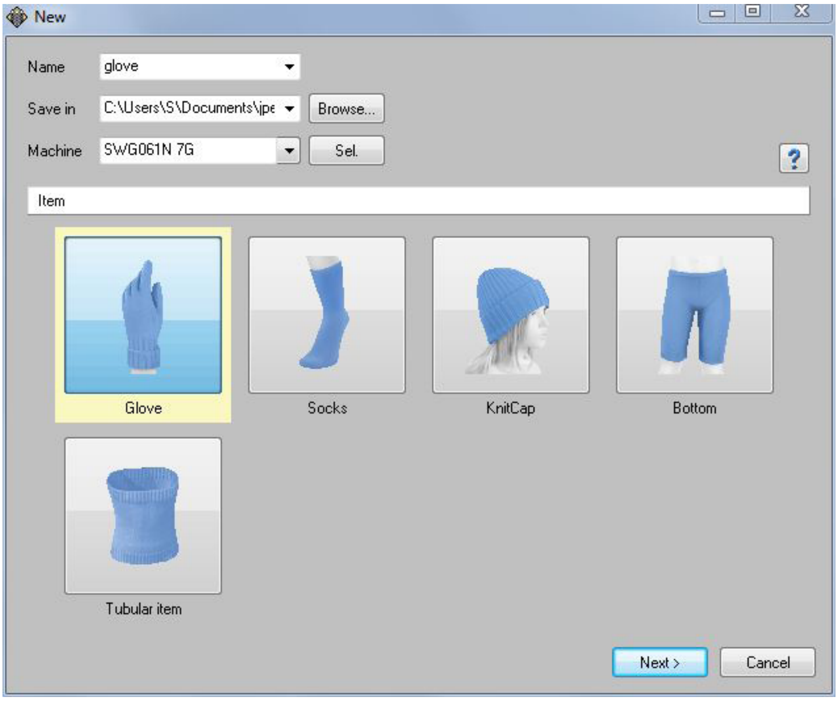
# //Appendix A: Cuztomization Options for a Glove Created in the KnitPaint Software Wizard



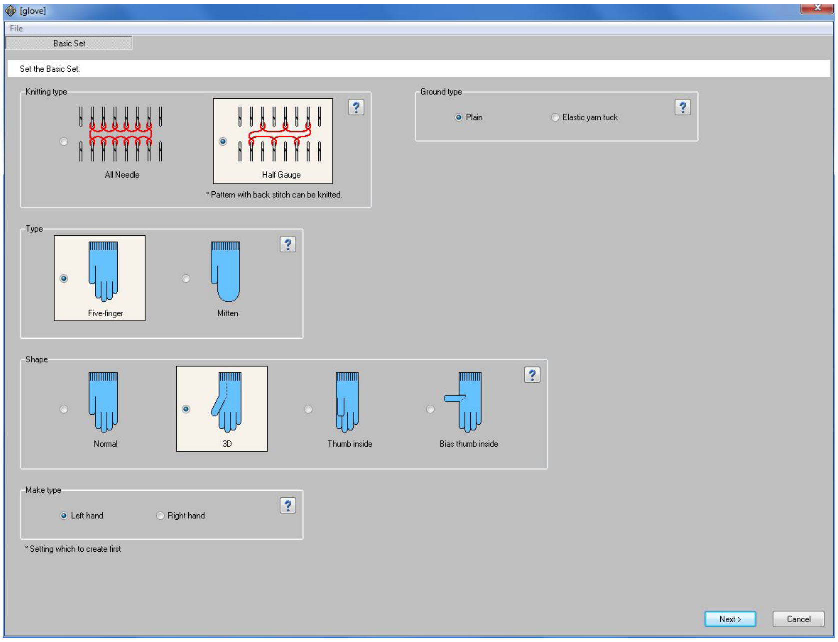
...olour 2 balls.
...sting Colour 1 ball.
...OUSERS (Both Sizes) 6 balls.
...front seam—
... 9 ins. Size B 10 ins.
...g seam (with cuff turned back)
... 13½ ins. Size B 14½ ins.
...edles: 1 pair each Nos. 9, 10, 11 and 12
...

# Appendix A: Cuztomization Options for a Glove Created in the KnitPaint Software Wizard

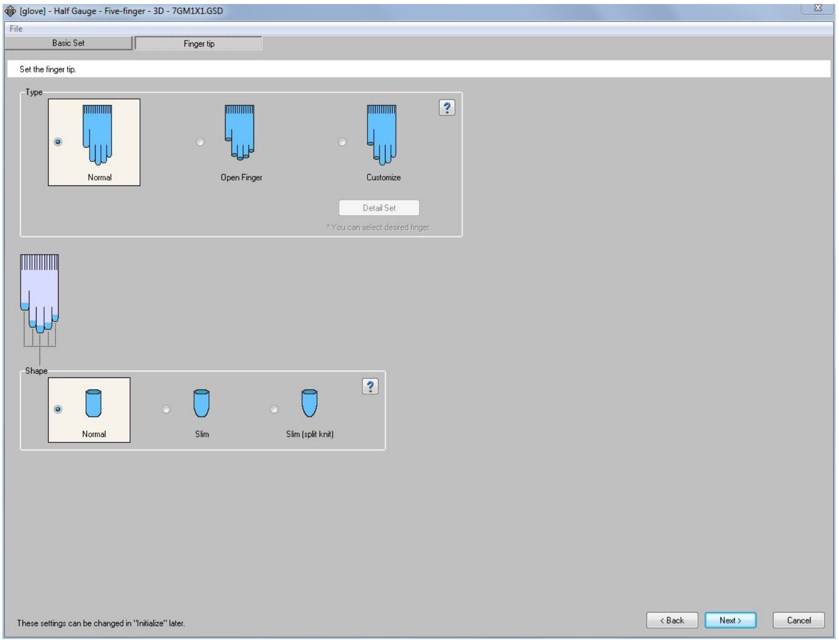
These are the screens shown to the user when they opt to create a glove in Shima Seiki's KnitPaint software wizard. All images in this appendix are from Shima Seiki's KnitPaint, accessed May 3, 2019. Numbers and descriptions are my own and correct to the best of my knowledge.



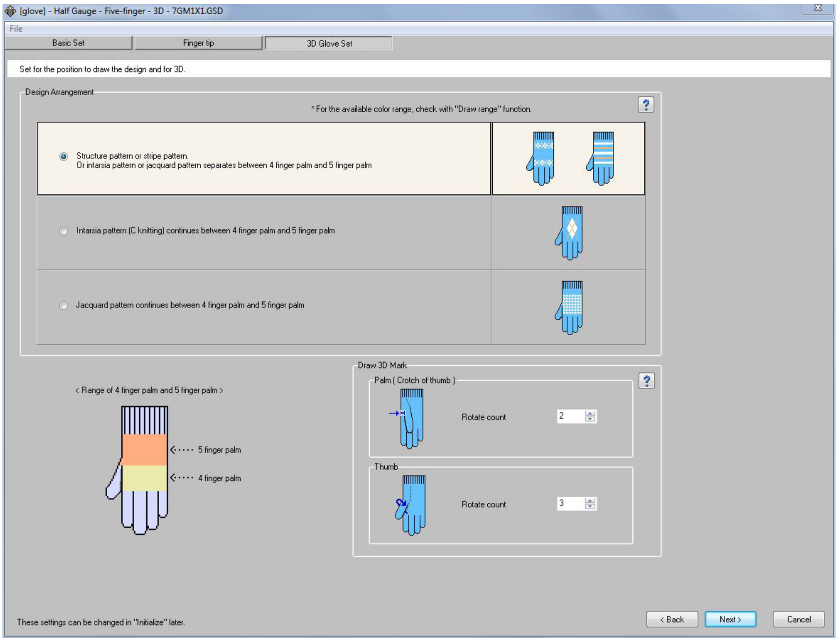

1 User selects which type of object they want to make out of the pre-sets available for the SWG061N knitting machine. User has "Glove" selected.



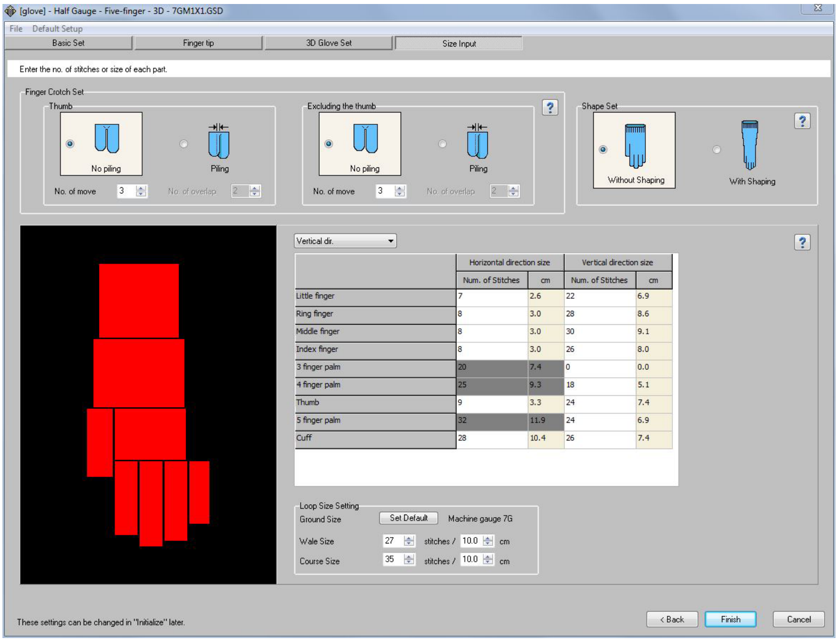

2 After user has selected glove, s/he may choose whether they want to knit full or half gauge, and the silhouette of the glove.



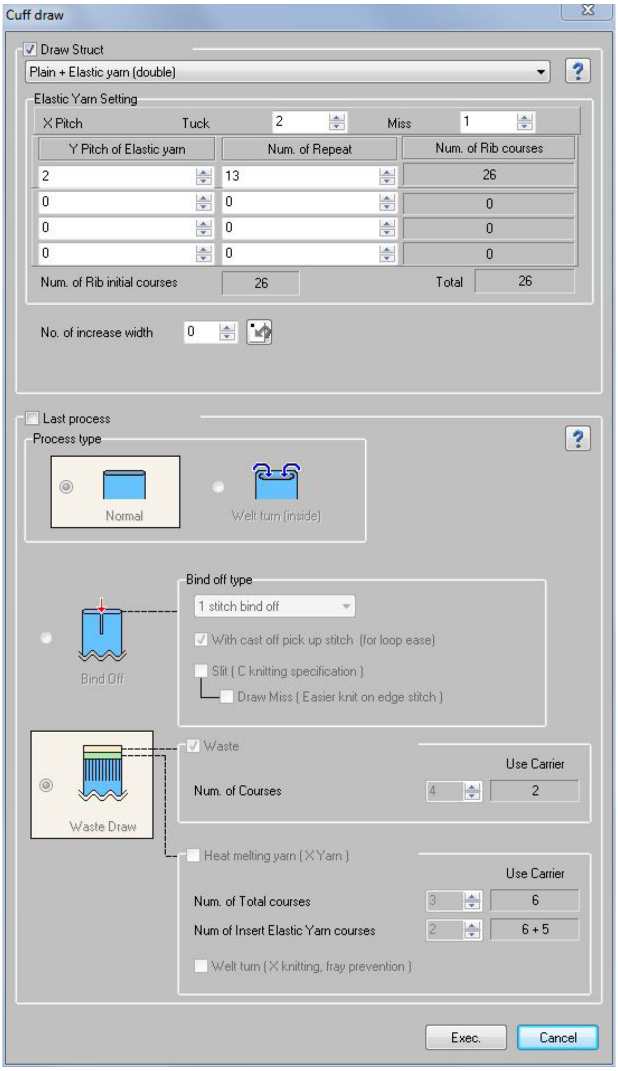

3 User may select the silhouette and style of the fingertip.



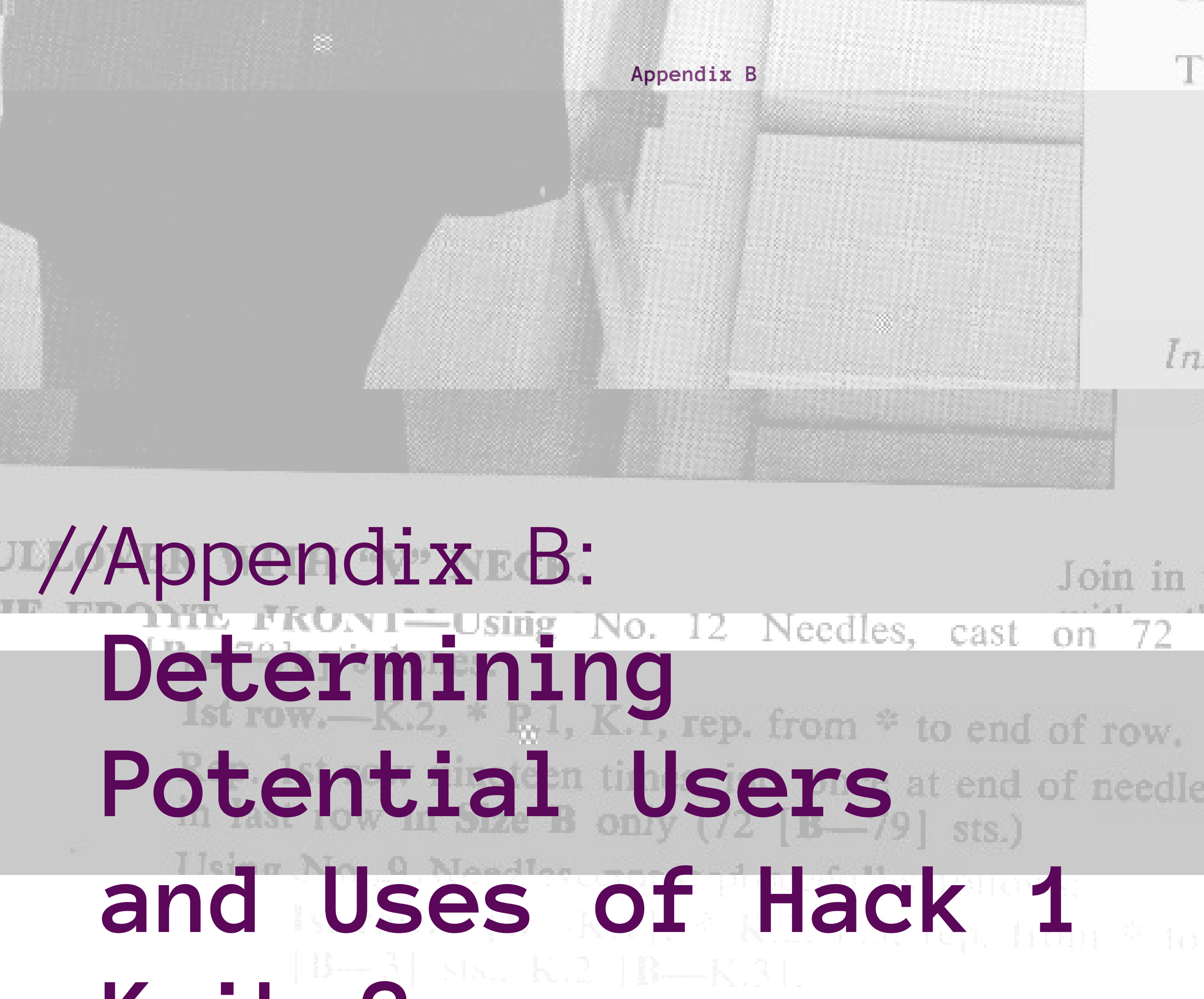
4 User chooses what kind of knit technique they will use if they wish to draw patterns on the glove.



5 User is able to change the length/height of various parts of the glove.




❻ User is able to choose how they wish to bind off (finish the edge of) the glove, and some other construction details.



# //Appendix B: Determining Potential Users and Uses of Hack 1 Knit 2

ENSION: To get these measurements [illegible] absolutely necessary to work at a tension to produce 13½ stitches to 2 inches in width measured over plain, smooth fabric. Check tension—see page 17.

*structions are for smaller size A [illegible] size B is shown thus [B—...].*

---

wool and work on remainin[illegible] respond with other side, omitting [illegible] at centre front in Size B.

**THE BACK**—Work exactly as given for Front to **. Cast off 3 [B—3] sts. at beg. of next 2 rows, then dec. once at each end of needle in every [illegible] row five times

(56 [B—63] sts.).

last 2

Continue in patt.

# Appendix B: Determining Potential Users

1 “AYAB – all yarns are beautiful,” AYAB, accessed October 29, 2018. http://ayab-knitting.com.

2 Becky Stern, “Electro-knit,” adafruit, last updated October 28, 2018. https://learn.adafruit.com/electroknit.

3 Mike Press, “Handmade Futures: The emerging role of craft knowledge in our digital culture,” NeoCraft: Modernity and the Crafts (2007): 249.

4 E.g., Parsons, RMIT, the Aukland University of Technology. See Digital Machine Knitting: Challenges for more information.

5 Jane Taylor, “The technical designer: a new craft approach for creating seamless knitwear,” (PhD diss., Nottingham Trent University, 2015): 99.

6 Kazunori Takada and Emi Urabe, “These Hi-Tech Knitting Machines Will Soon Be Making Car Parts,” published October 2, 2017. https://www.bloomberg.com/news/articles/2017-10-01/heir-to-1-9-billion-knitting-empire-is-taking-it-into-car-parts.

7 Emma Tucker, “3D Knitted Furniture Arrives at IKEA,” published December 12, 2016, https://www.dezeen.com/2016/12/12/ikea-3d-knitted-armchair-ps-2017-collection-design-sarah-fager.

8 “The Girl and the Machine,” accessed March 5, 2019, http://www.thegirlandthemachine.com/en.

| User | Why They Might Be Interested |
|---|---|
| **Hobbyists**<br><br>Knitters, hackers, crafters, and other types of makers who create thingsfor reasons other than monetary gain | • My horizon scan revealed products like “AYAB” and “Electro-knit” aimed at hobbyists and makers, suggesting an interest and a market[1, 2]<br>• Theorists such as Mike Prest suggest that traditional methods of creation are reinvigorated through technology[3]<br>• My maps of a near-future knitting landscape helped identify that there are certain types of hobbyists driven by digital technologies that would be interested in whole-garment knitting technology if it were more available to use |
| **Educational Institutions**<br><br>Researchers, teachers, and students affiliated with universities, colleges or other learning facilities | • My horizon scan revealed that some educational institutions do offer whole-garment knitting technology for students or staff[4]<br>• Taylor’s paper suggests that the current infrastructure in schools can’t support many students using expensive and challenging to learn whole-garment knitting equipment, suggesting a need for better-documented offerings[5]<br>• My mapping exercise suggested that educational facilities may be performing very specific or experimental tasks not well-suited by the rigid current visual interface |
| **Artists**<br><br>Professional artists working with knitted materials to create predominantly non-functional work | • My horizon scan identified artists who are already working with experimental knits<br>• Franz Petter Schmidt, during our interview, identified openness and involvement with a community as important to his practice, suggesting that the open-source aspect of my project may resonate with some artists<br>• In my mapping exercise, I determined that artists may be interested in experimental production methods or outcomes |
| **Independent Designers (General)**<br><br>All designers conceptualizing functional goods for any field outside the mass market | • Some positive aspects associated with whole-garment knitting, like 3D shaping, or mass-customization, may be currently difficult for independent designers to use given the current inaccessibility of software and hardware<br>• My horizon scan suggested that companies are only beginning to work with whole-garment knitting outside of clothing, for things such as automotive parts, and furniture, suggesting an opportunity area[6, 7]<br>• My mapping activity suggested that creators working outside of the mass market may have more opportunity to explore experimental ways of making |
| **Independent Designers in Specialized Fields**<br><br>Designers conceptualizing functional goods for some specific area outside of the mass market | • Some positive aspects associated with whole-garment knitting, like 3D shaping, or mass-customization, may be currently difficult for independent designers to use given the current inaccessibility of software and hardware<br>• Customization has been a fashion trend in recent years, as suggested by companies identified in my horizon scan (see **State of the Art**). Focusing on fashion designers may allow me to explore this area in detail<br>• My mapping activity suggested that designers working outside of the mass market may have more opportunity to explore experimental ways of making |
| **Mass Market Designers**<br><br>Designers conceptualizing functional goods to be manufactured and sold in large quantities | • In my horizon scan, I identified companies such as The Girl and The Machine that view the lack of excess yarn used in whole-garment knitting as a sustainable alternative to current production methods, which is of major importance to fast fashion[8]<br>• Scholars have written extensively about how company cultures and role expectations have left designers unable to learn whole-garment knitting techniques given the challenging nature of the software (see **Digital Machine Knitting: Challenges**). Creating the groundwork for software that is easier to decipher for designers may help mitigate this situation<br>• Hege Meilstrup and Axel Haugan identified the lack of transportation needed for on-site manufacturing, and on-demand production (reducing unsold goods) as beneficial for sustainability<br>• Meilstrup and Haugan also identified whole-garment knitting as a draw to brick-and-marter shopping experiences |

# and Uses of Hack 1 Knit 2

| Potential Use | Target? | Reasons for Inclusion/Exclusion |
|---|---|---|
| **Small-run Manufacturing**<br><br>Enabling makers to knit increased quantities of their designs compared to hand-knitting or automatic machine knitting | No | • Increased production capacity is an inherent benefit of whole-garment knitting<br>• A project focusing on this virtue might imply research that is more concerned with the commercial realities of whole-garment knitting, which I consider a step that should be performed after the practicalities of whole-garment knitting are better understood and more accessible to learn |
| **Mass Customization**<br><br>Digital platforms allowing users to customize the fit or dimensions of a knit item | No | • Custom sizing in particular implies a lot of technicalities that are beyond the scope of this project |
| **Unique Design Goal**<br><br>Designers wanting to create an object with a unique silhouette that can't easily be accomplished with the existing SDS-ONE APEX3 software suite | Yes | • In my horizon scan, I identified that it is often difficult for designers and technicians to create items that aren't partially templated in the software<br>• Investigating how to create different silhouettes and shapes could benefit a wide range of designers as there isn't much available research available in this area related to whole-garment knitting technology |
| **Experimental Design Methods**<br><br>Some makers may be interested in the experimental nature of using coding to facilitiate the creation of designs | Yes | • In the future, Knitout may be used as a basis for a visual interface<br>• Regardless, there are currently limited ways of knitting with whole-garment knitting machines that allow users with an interest in creative computing to participate<br>• Even as an experiment, I think it's a valid exercise to examine how designers might leverage code as part of their knit design practice |

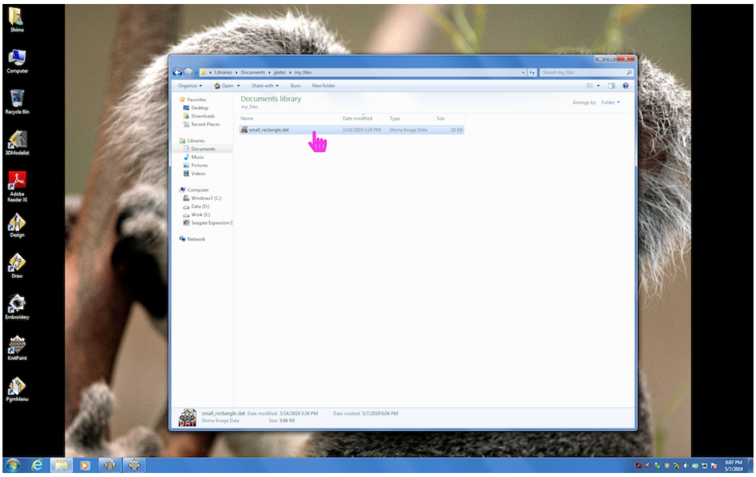
# //Appendix C: Processing a Knitout-generated DAT File in SDS-ONE APEX3

easurements it is
rk at a tension to

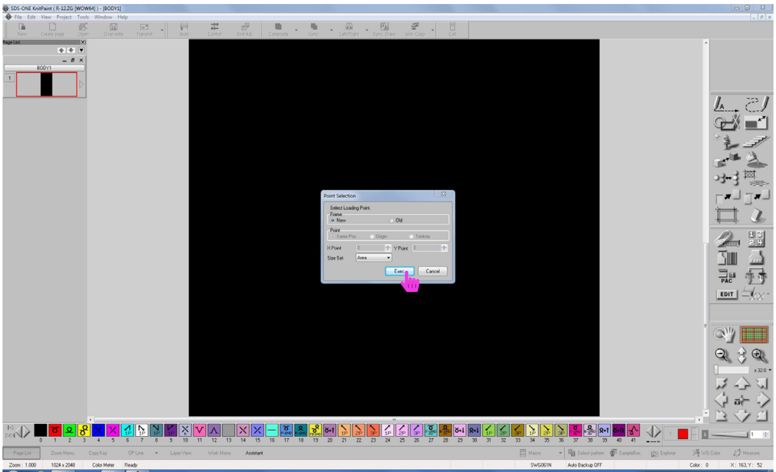
# Appendix C: Processing a Knitout-generated DAT File in SDS-ONE APEX3

This appendix consists of a step-by-step guide to generate a .000 and (optionally) a .999 file from a .DAT file, in order to knit it with an SWG061N whole-garment knitting machine. All images in this appendix are from Shima Seiki's KnitPaint, accessed May 3, 2019. Numbers, highlights and descriptions are my own. These steps take place after the user has generated a .DAT file using Carnegie Mellon's knitout-to-dat.js process.[9]

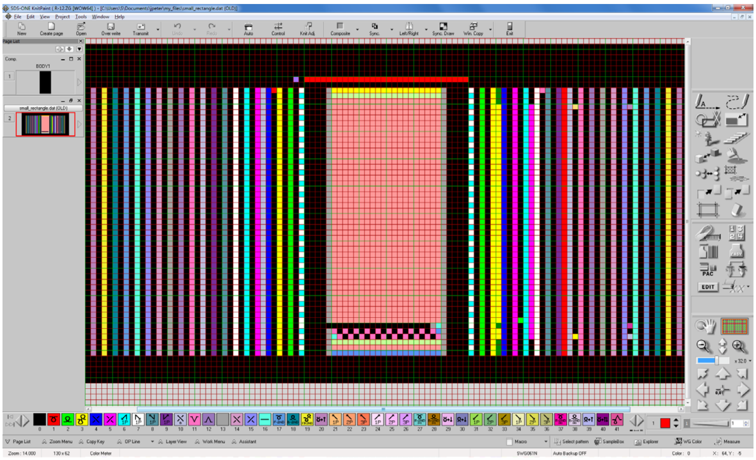
9 "knitout-backend-swg" (Github code repository), last updated April 21, 2019. https://github.com/textiles-lab/knitout-backend-swg.



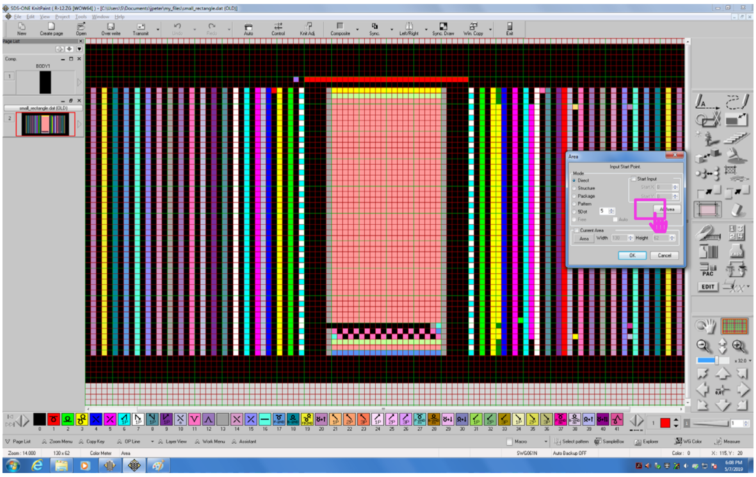
1 After copying the file onto the SDS-ONE APEX3 computer via USB or other method, double click it.



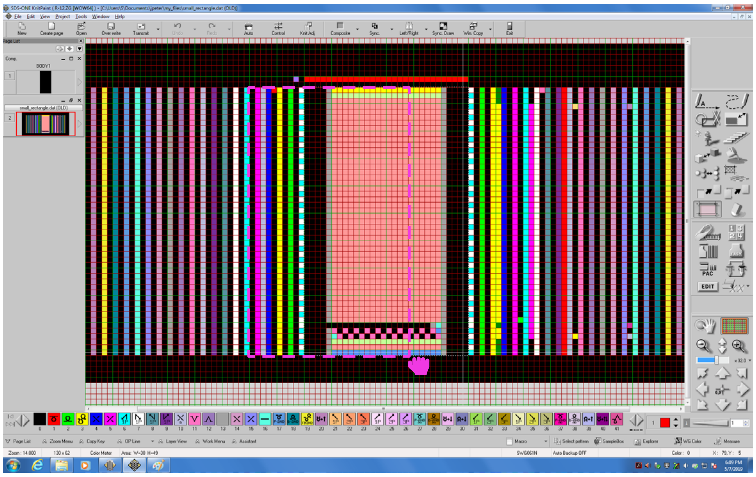
2 KnitPaint will load with the following dialog box open. Click "Exec."



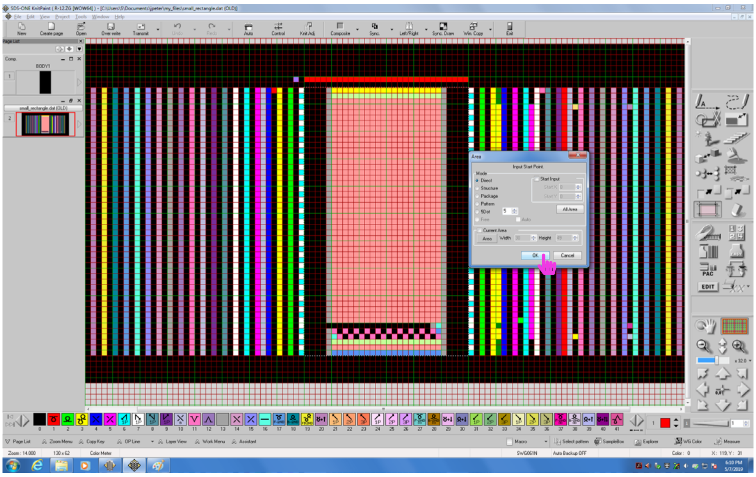
3 The file should load.



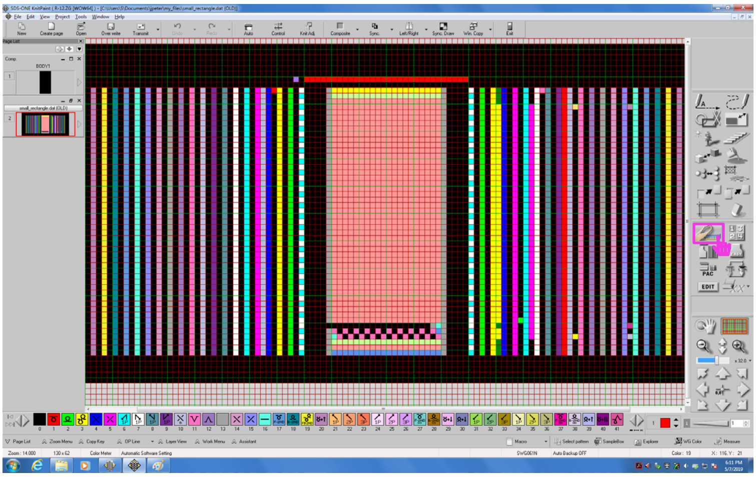
4 Click the “Area” button in the right toolbar.



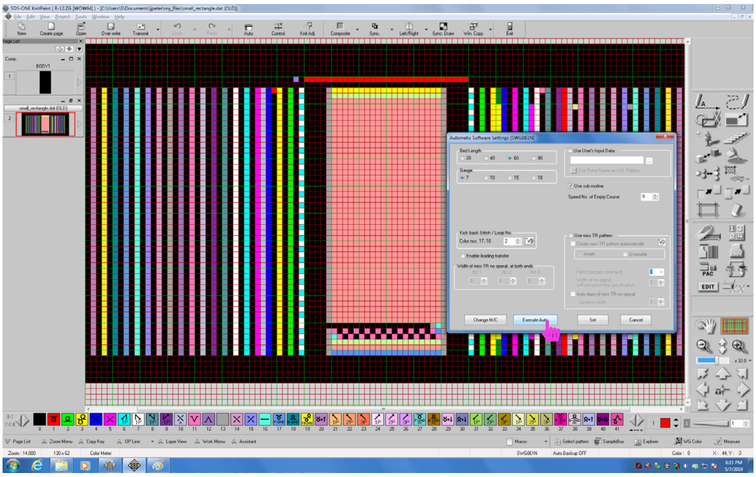
5 Drag a rectangle around the centre part of your design, not touching the red bar at the top or the option lines to the left and right.



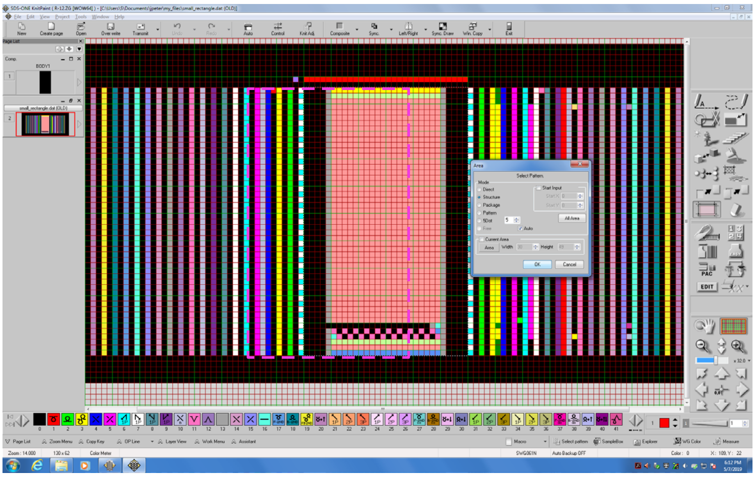
6 After releasing the selection, the Area menu will appear again. Click “OK.”



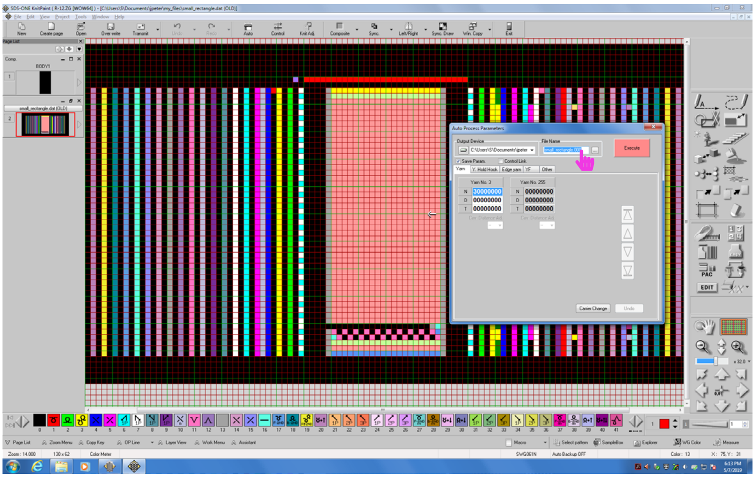
7 Click the “Auto Process” button in the right toolbar.



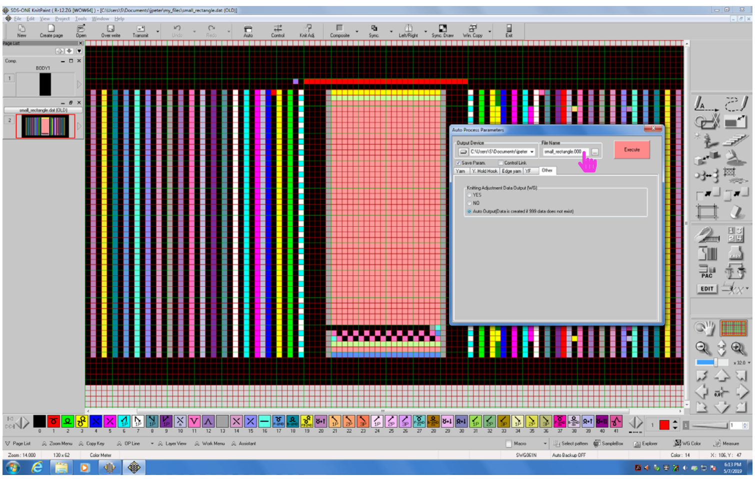
8 On the “Automatic Software Settings” menu that pops up, ensure the selected machine (in square brackets at the top of the window) is SWG061N, and that the settings for “Gauge” and “Bed Length” are set to 7 and 60, respectively. Then click “Execute Auto.”



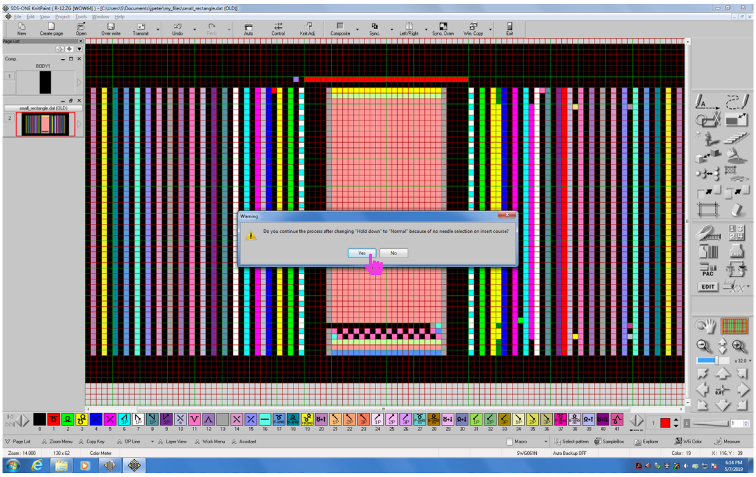
9 The “Area” menu will appear again with your previous selection already highlighted. Click “OK.”



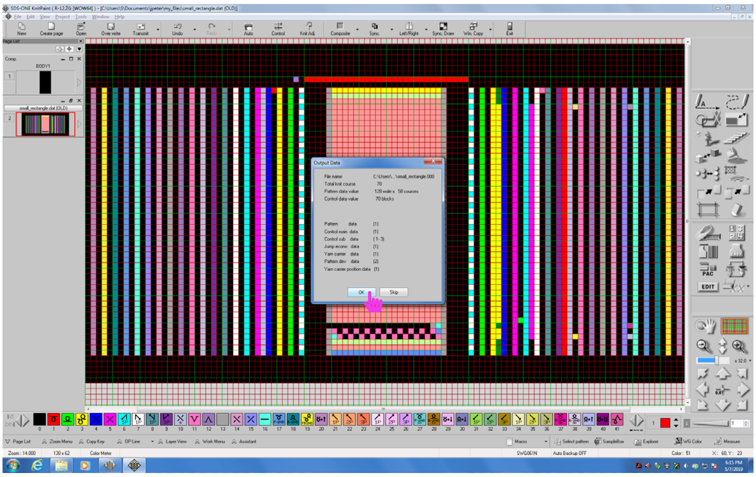
10 The “Auto Process Parameters” menu will pop up. If you don’t want to create a custom .999 file, click “Execute.”



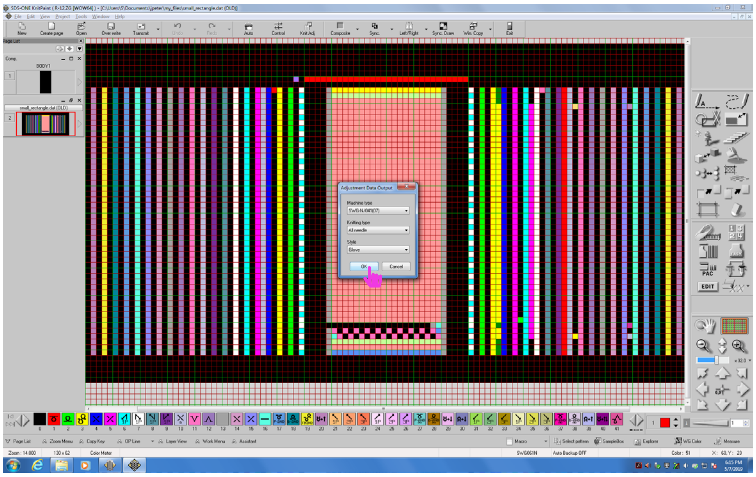
11 Optional: If you would like to generate a .999 file, click the “Other” tab and select “Auto Output.” Otherwise, you will use whatever settings were last used on the knitting machine. Then click “Execute.”



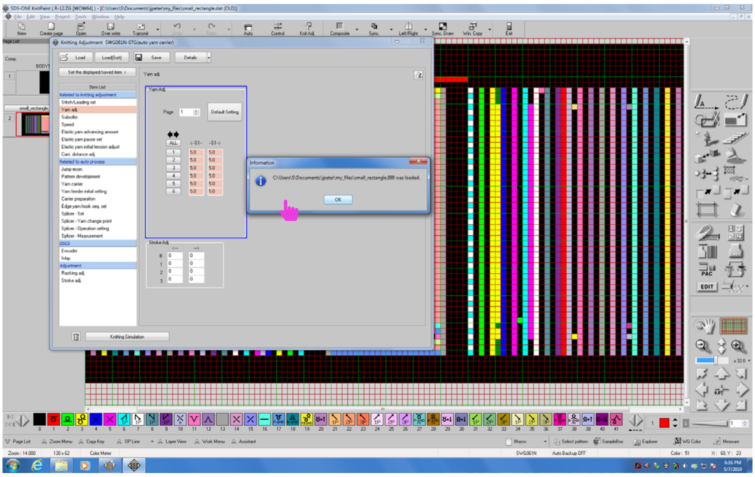
12 This warning message will pop up. Click “Yes.”



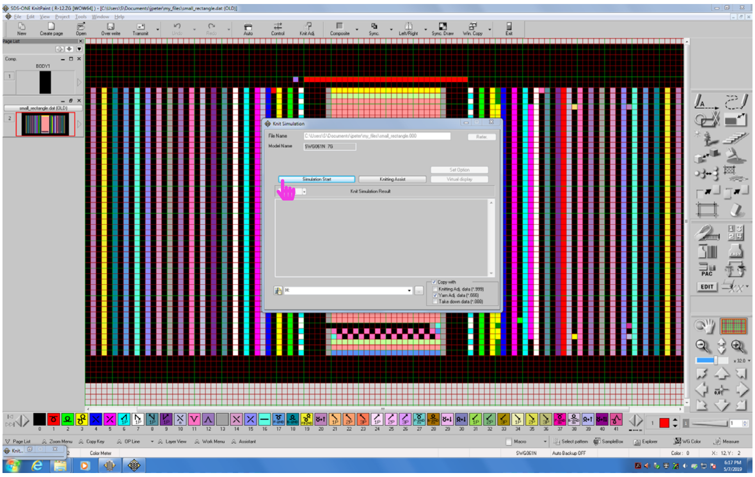
13 Click “OK” on the “Output Data” pop-up that comes up, which provides a summary of the knitting pattern.



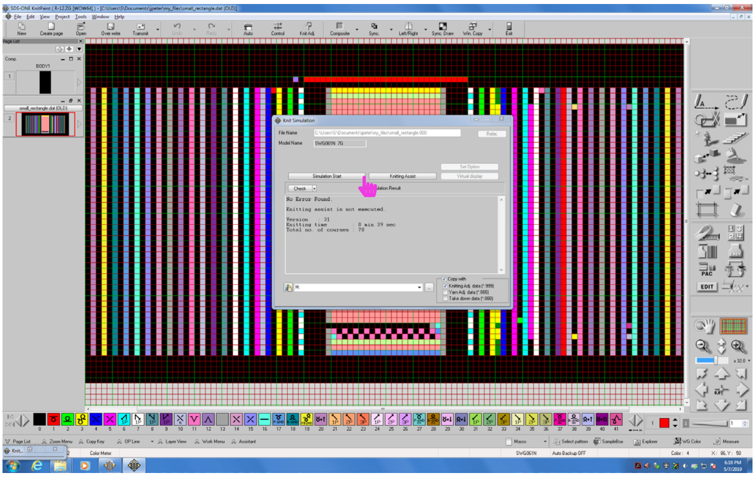
14 Optional: If you performed step 11, you will get the “Adjustment Data Output” menu, which will generate a generic .999 file based on styles available through the automatic wizard. Press “OK.”



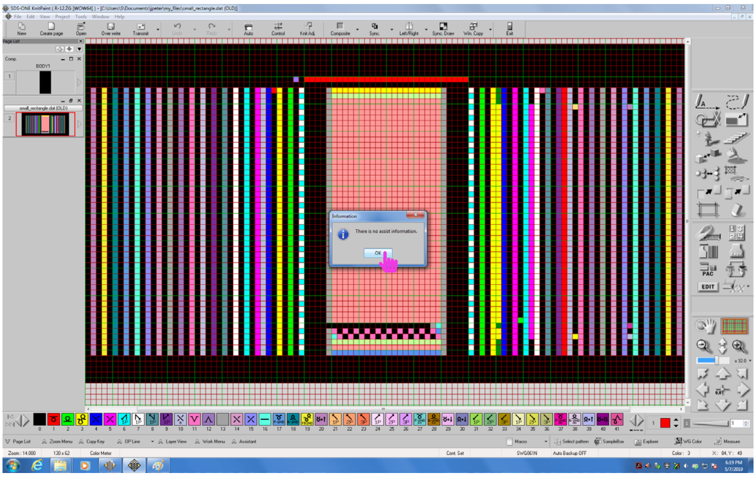
**15** Optional: If you performed step 11, this message will appear. Click “OK.”



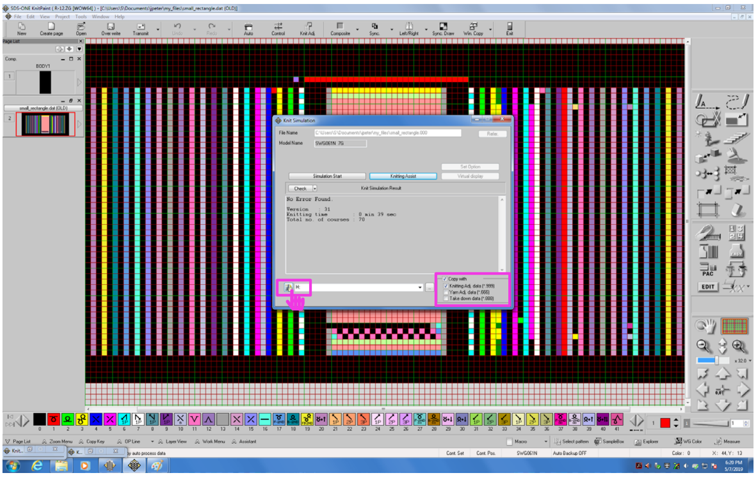
**16** The “Knit Simulation” menu will pop up. Click “Simulation Start.”



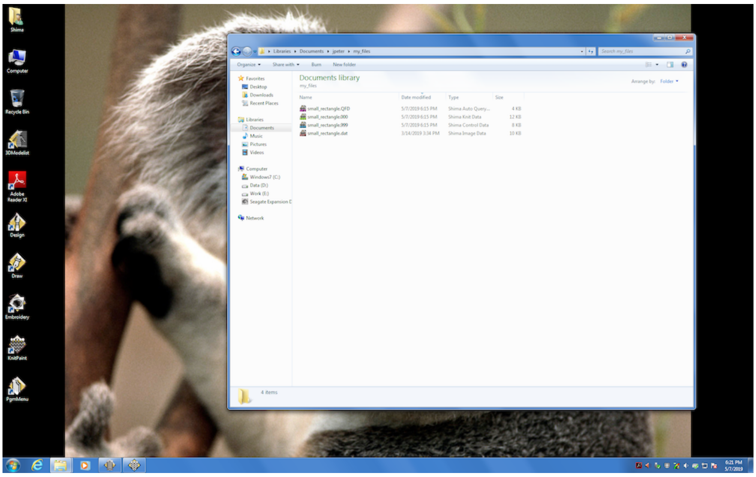
**17** If there are no breaking errors with your pattern, a message saying “No Error Found” will appear, along with an estimate of knitting time. If there are issues, adjust your pattern. Click “Knitting Assist.”



**18** If there are no warnings about potential issues in your knitting piece, the following message will occur. Click “OK.”



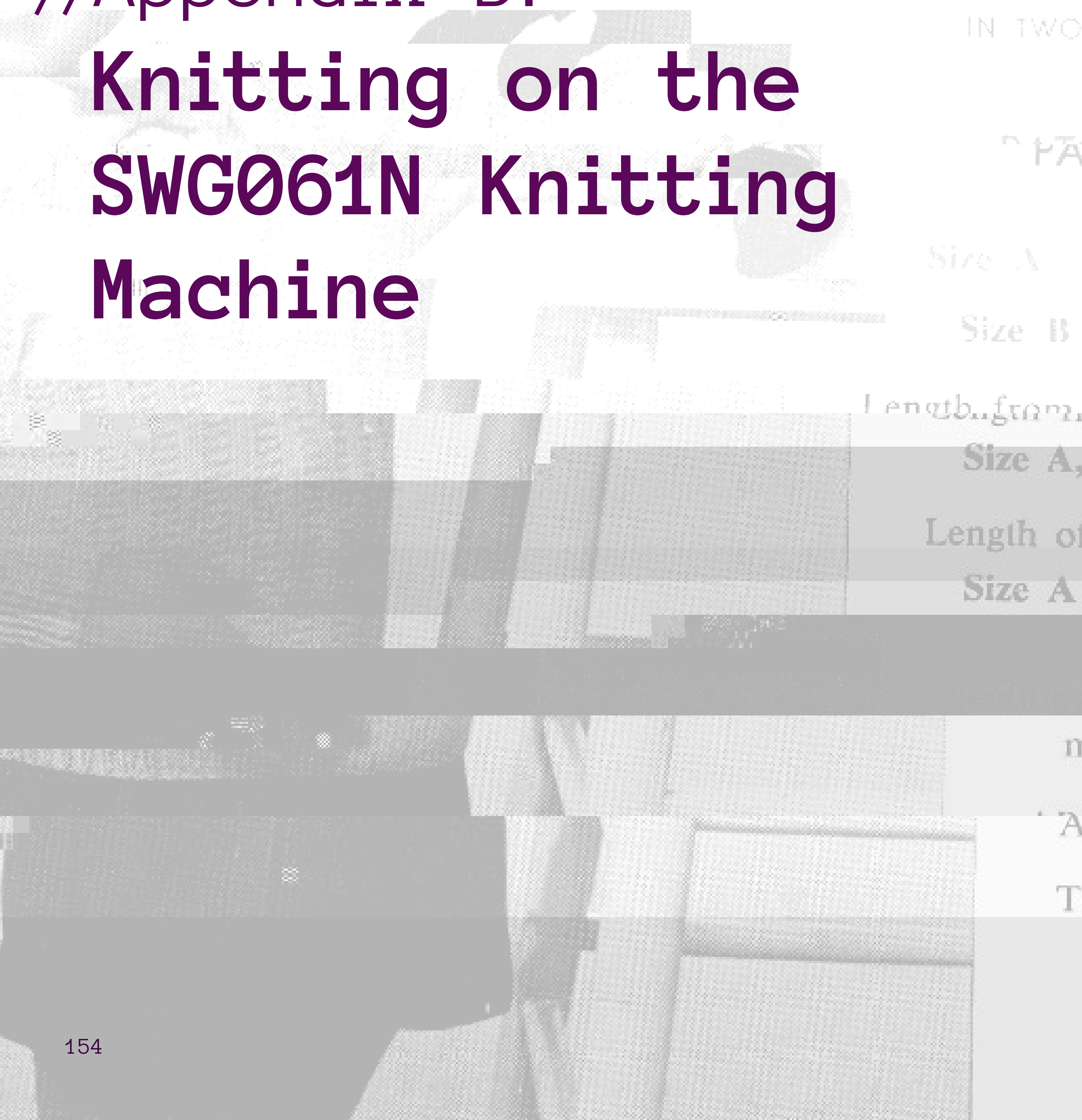
**19** Optional: Copy the .000 and .999 files to a USB using the field at the bottom of the menu. If you generated a .999 file, ensure “Copy with” and “Knitting Adj. data” are checked.



**20** Optional: If you did not perform step 19, instead copy the .000 file that has been generated in the same folder as your original .DAT file onto a USB. If you chose to generate a .999 file, copy that file as well.

# Appendix C

# //Appendix D: Knitting on the SWG061N Knitting Machine



SIZES — WITH "V"
OR ROUND NECK

TONS BLUEBELL CREPE

22 inch underarm . . . 5 ozs.

24 inch underarm . . . 6 ozs.

top of shoulder—
. . . . 12 ins. **Size B,** . . . . 13 ins.

f sleeve from underarm—
. . . . 9 ins. **Size B** . . . . 10 ins.

measured on a Beehive Needle Gauge.

ABBREVIATIONS: See page 17.

TENSION: To get these measurements it is absolutely necessary to work at a tension to produce 13½ stitches to 2 inches in width measured over plain, smooth fabric. Check tension—see page 17.

# Appendix D: Knitting on the SWG061N Knitting Machine

This appendix consists of a guide to loading a knittable .000 file and, optionally, a .999 file onto an SWG061N knitting machine. The workshop supervisor at KHiO taught me these steps, and I am reproducing them in this guide of my own volition. I have chosen to include this appendix as, to my knowledge, no similar guide is available as an online resource, and I never came across these steps in any of the official help guides. Photos have been edited to improve contrast on the display screen in order to increase legibility.

1 Turn the red knob on the right side of the machine clockwise.


2 Wait until the Shima Seiki logo appears on the display screen.


3 Press the “on” button on the right side of the machine.


4 Wait until it glows green.

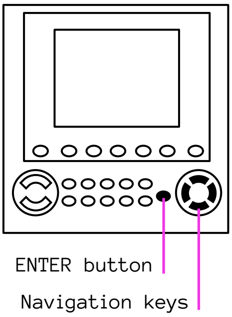

5 Connect your USB drive to the receptacle on the right side of the machine.


6 A message will appear on saying “DRIVE WITH OPERATION SWITCH.” If the message doesn’t disappear on its own, press the second grey button on the left to “CANCEL.”

7 Press the green button below the display screen. There will be a noise and some movement from the machine.


8 Navigate to and enter[10] the “DISK OPERATION” menu.

10 Unless otherwise stated, navigation is performed by using the four keys arranged in a circle to the bottom right of the display screen, as well as the “ENTER” button to confirm an action.




9 Navigate to and select “READ” with the “ENTER” button. The machine will take a few minutes to refresh and then display the files stored on your USB.

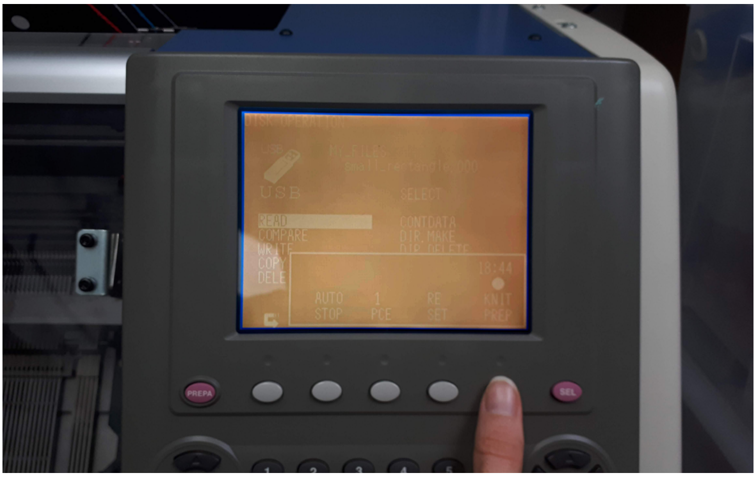

10 Optional: if you are loading a new .999 file, navigate to it and press “ENTER.”


11 Optional: If you performed step 10, navigate up to “EXEC” on the menu that appears, and then press “ENTER.”


12 If you performed steps 10 and 11, you will be returned to the main menu. Navigate to and enter the “DISK OPERATION” menu.


13 Navigate to and press “ENTER” on the .000 file. As shown in step 11, navigate up to “EXEC” on the menu that appears, and then press “ENTER.”


14 Press the button labeled “PREPA” to the bottom left of the display screen.

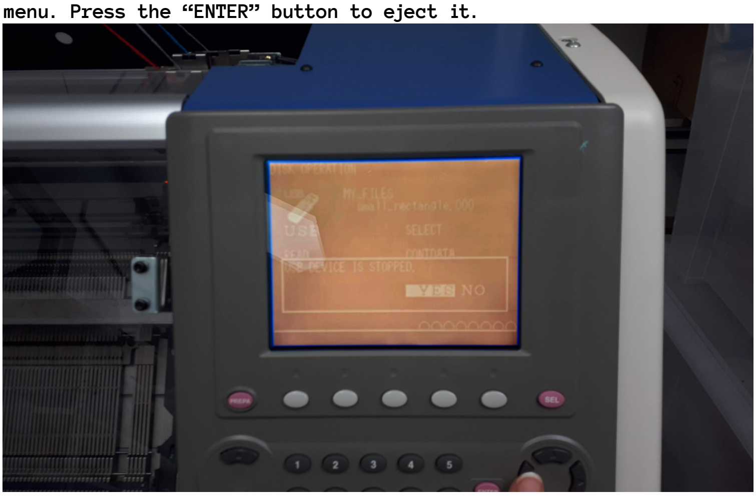



**15** Click the rightmost grey button below the display screen to select "KNIT PREP." The machine will make some noise for a few seconds.


**16** If everything worked well, a message will appear saying "[ERROR] 3003-0000 FINISH." Press the second grey button to the left to exit the message.

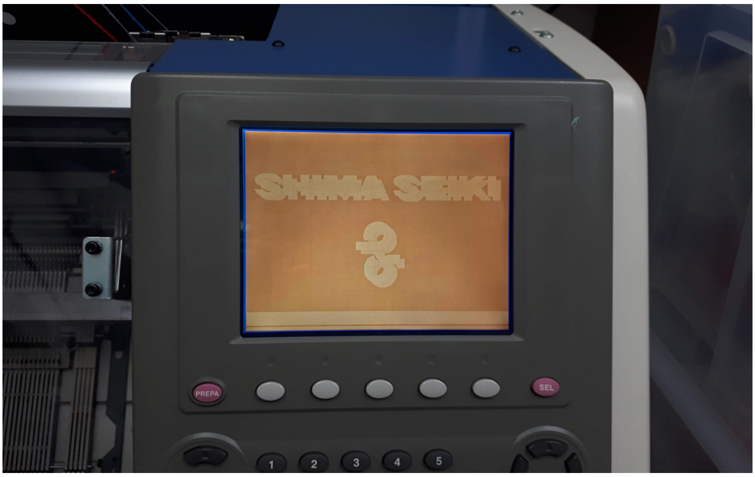

**17** Press the green button below the display screen to knit.


**18** Once the item has knitted, in the “DISK OPERATION” menu, navigate to the icon of a USB drive at the bottom of the “DISK OPERATION” menu. Press the “ENTER” button to eject it.




**19** Navigate to “YES” and press the “ENTER” button.


**20** Press the “on” button to begin turning the machine off.




21 Wait for the Shima Seiki logo to appear on the display screen.

22 Turn the red knob counter-clockwise to finish turning the machine off.


Patons

# //Glossary

**3D knitting:** A colloquial term often used by media outlets to describe a range of different knitting technologies. Often describes whole-garment knitting (see “Whole-garment knitting”).

**Carrier:** See “Yarn carrier.”

**Carnegie Mellon Textiles Lab:** A research group based out of Carnegie Mellon University, led by Jim McCann. They developed the Knitout file specification, among other work with technology and textiles.

**Cast off:** The process of binding off columns of knitting so that it will not unravel. In a large rectangular knit piece, like a scarf, this process would occur after the last row of knitting.

**Cast on:** The process of making the first few stitches in any sort of knitting. Cast on stitches are generally formed through a different process than other stitches to prevent the knit piece from unraveling.

**DAT:** Or “dat.” A file format produced by KnitPaint (and presumably other SDS-ONE APEX3 software programs) to create files that can be interpreted by Shima Seiki knitting machines in order to create a knit item. DAT files can also be created from Knitout files using a program developed by the Carnegie Mellon Textiles Lab.

**Debug:** To work towards removing an error in a software program.

**Hardware:** The physical components making up a computer or other electronic item.

**Kniterate:** A whole-garment knitting machine created by a start-up. They are significantly less expensive than Shima Seiki machines.

**Knitout:** An open-source file format developed by the Carnegie Mellon Textiles Lab. Knitout files represent knit objects that can be produced by knitting machines. For Shima Seiki machines, Knitout files must be first processed with a program to convert them into DAT files. They are designated by the file extension .Knitout or .k.

**KnitPaint:** A software program on Shima Seiki’s SDS-ONE APEX3 computers. Users draw squares to indicate the structure of a knitted piece, with each square coloured differently to represent a different type of stitch. KnitPaint is used to create .dat files.

**Maker:** A person who creates usually physical things. People who identify as a "maker" often take on DIY-projects as hobbies, often with a technological focus.

**Maker culture:** A subculture characterized by various physical and social entities related to DIY-enthusiasts. This can include both online entities, like message boards, and physical entities, like makerspaces (communal workplaces where makers can create personal projects).

**Maker movement:** The relatively recent increase in interest in DIY production, particularly technology-related DIY productions. See also "maker culture."

**Option lines:** Part of a knitted pattern when viewed in KnitPaint. Option lines appear to the left and right of the structure pattern. These lines contain data such as which yarn carrier is to be used, and other operational data.

**Open-source:** Technology where users have access to the technology's source code. Users are encouraged to modify open-source software. Advocates of open-source will highlight how open-source software may be more robust due to the large number of people who can view or contribute to a project's code, and the ethical virtue of transparent development. A full definition of open-source can also be found at the Open Source Initiative's website: https://opensource.org/about.

**Production Knitter:** A person who knits other people's designs outside of a commercial knitting factory. The items they knit may be used as a sample for the designer to send on to a larger manufacturer, or the items themselves may be sold.

**Rack:** Racking means to move the back bed of needles on a knitting machine, so as to change how the back bed aligns with the front bed of needles. Racking is often used when transferring yarn between the two beds.

**Repository:** In the context of programming, a repository is a collection of code files related to a project.

**SDS-ONE APEX3:** The computer system used to work with many of Shima Seiki's knitting machines. These computers have a host of software to design garments, including KnitPaint.

**Shima Seiki:** A leading manufacturer of industrial-grade equipment for textile creation. They invented, and currently lead the market in, whole-garment knitting technology.

**Software:** Programs that can be used on a computer or other electronic item.

**Software Wizard:** A user-interface in software programs that helps a user through a complicated process through a series of dialog windows. Interaction on the part of the user is minimal: generally, is it limited to making selections from pre-defined lists at different stages of the process.

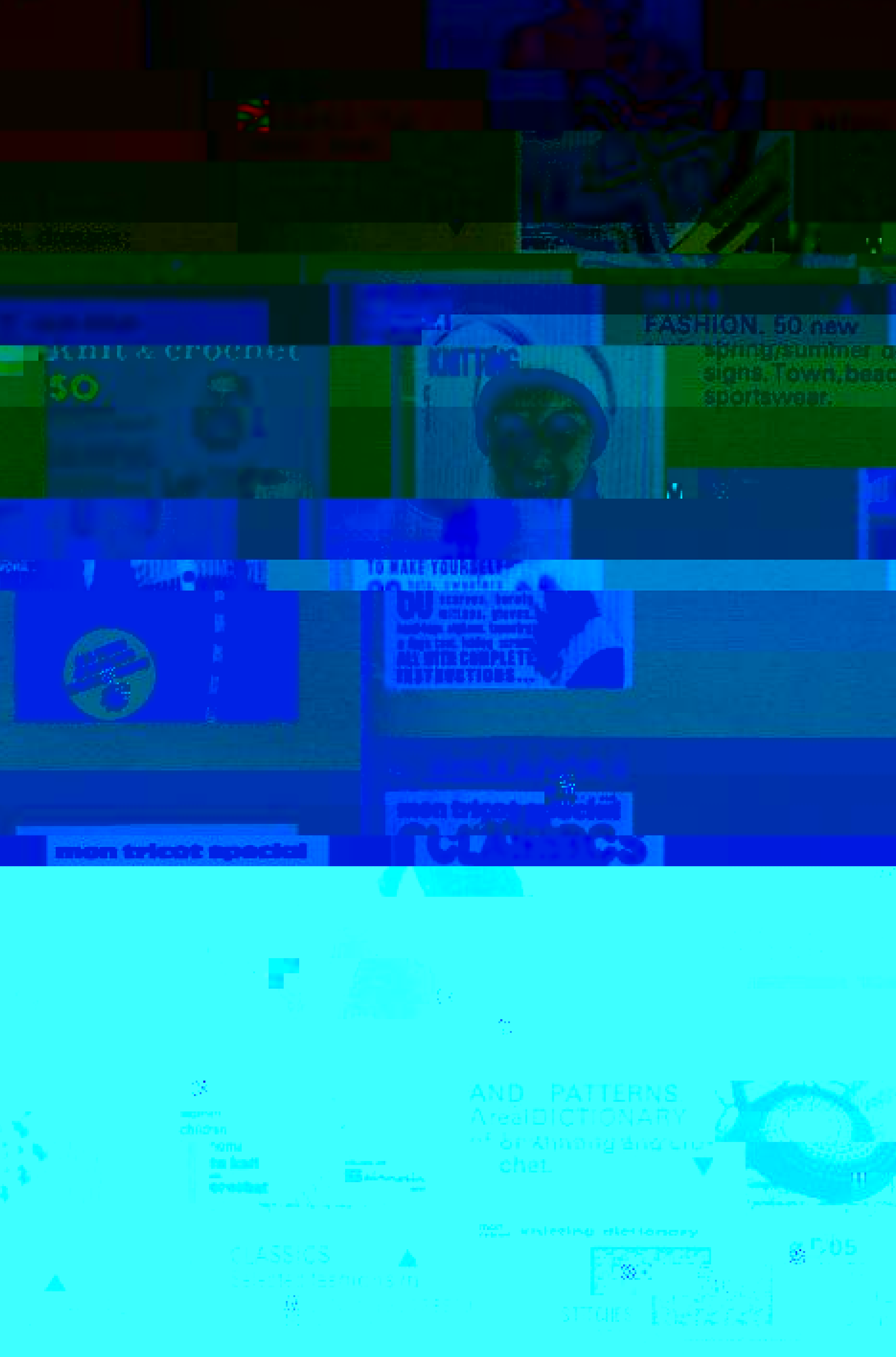
**Structure Pattern:** The middle portion of a knitted pattern when viewed in KnitPaint. This portion of the pattern contains data such as what type of operation (e.g., knitting, transferring yarn to another needle) is performed at a given place in a pattern, and what side of the textile the action is performed on (i.e., front or back).

**Tech pack:** A set of documents a designer or fashion brand will give to a manufacturer that includes detailed information on how the final garment should look.

**Yarn carrier:** The part of a knitting machine that feeds yarn to the needles so that knitting can occur. The term can refer to either or both the spool-like object holding yarn, and/or a small part of the machine that feeds yarn from the spool to the needles.

**Whole-garment knitting:** Also called “3D knitting” or “complete-garment knitting.” Whole-garment knitting is a special type of knitting enabled by whole-garment knitting machines. Whole-garment knitting machines are capable of knitting complete, seamless garments that don’t need to be assembled by the user.

**Wizard:** See “software wizard.”



knit & crochet
50
FASHION. 50 new
sportswear.
KNITTING
TO MAKE YOURSELF
60
scarves, berets
ALL WITH COMPLETE
INSTRUCTIONS...
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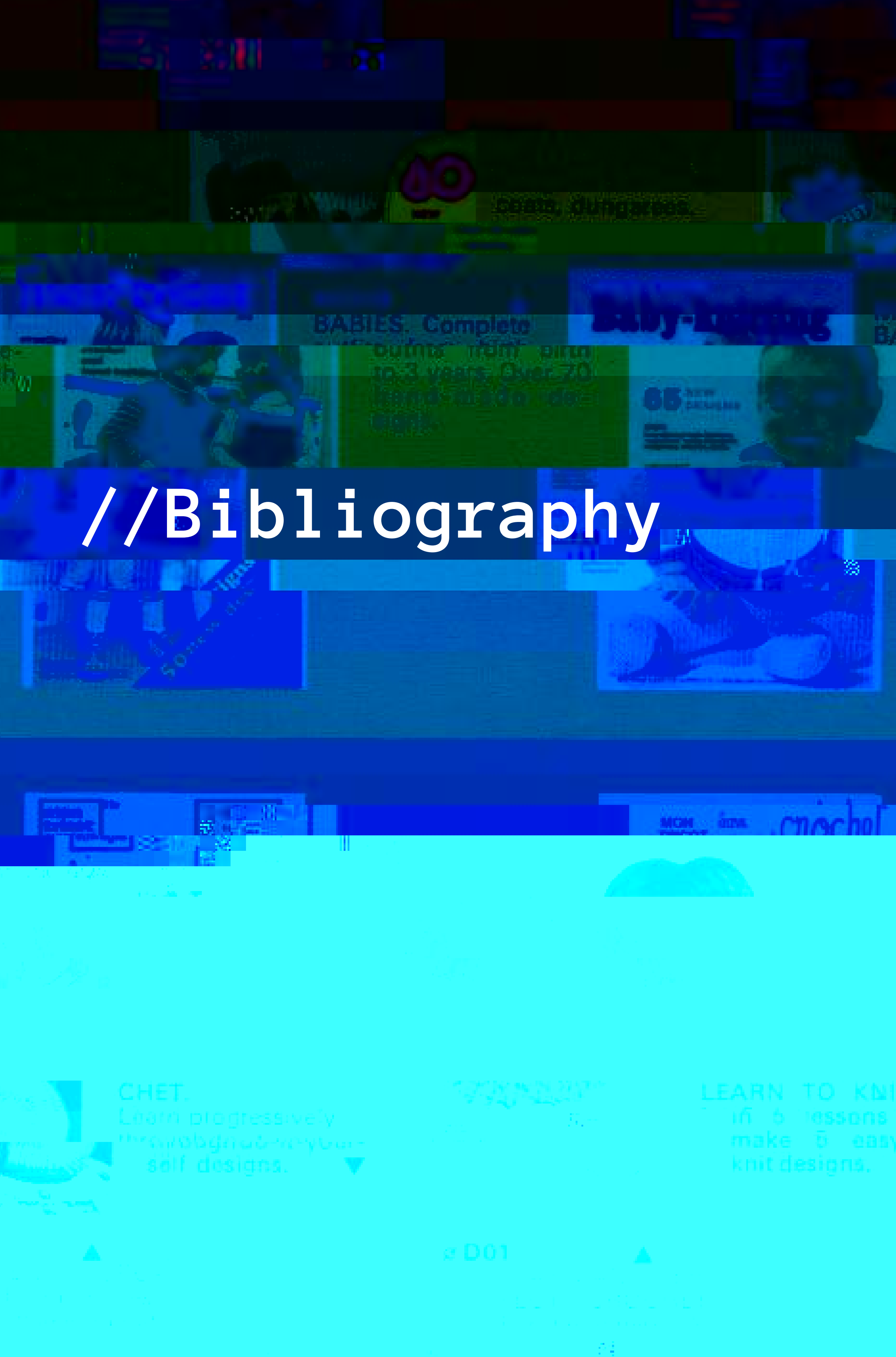
CLASSICS
AND PATTERNS
knitting dictionary
CLASSICS




# //Bibliography

"Adidas explores localised production with 'Knit for You' pop-up store," Knitting Industry, published April 10, 2017, https://www.knittingindustry.com/adidas-explores-localised-production-with-knit-for-you-popup-store.

Atacac. "Butterfly Tee," Atacac Webstore, accessed March 8, 2019, https://shop.atacac.com/collections/sharewear/products/butterfly-tee.

"autoknit" (Github code repository), last updated September 6, 2018. https://github.com/textiles-lab/autoknit.

"AYAB - all yarns are beautiful," AYAB, accessed October 29, 2018. http://ayab-knitting.com.

"AYAB Interface," Evil Mad Scientist, accessed November 6, 2018, figure 5. https://shop.evilmadscientist.com/productsmenu/835.

Bain, Marc. "Brands see the future of fashion in customized 3D-knitted garments produced while you wait," Quartz, published April 5, 2017, https://qz.com/949026/brands-including-adidas-uniqlo-and-ministry-of-supply-see-the-future-of-fashion-in-on-demand-3d-knitting.

Dudley, Sandra H. "Museum materialities: Objects, sense and feeling." Museum Materialities. Routledge, 2013.

Eckert, Claudia. "Managing effective communication in knitwear design." *The Design Journal* 2, no. 3 (1999): 29-42.

Hunter, Billy. "Max Mara: A champion of Shima Seiki WHOLEGARMENT technology." Published November 6, 2015. https://www.knittingindustry.com/max-mara-a-champion-of-shima-seiki-wholegarment-technology.

Klepp, Ingun Grimstad. "Knitting." Store norske leksikon. Last updated December 11, 2018. https://snl.no/strikking.

Kniterate. "Meet Kniterate," accessed October 29, 2018. https://www.kniterate.com/product/kniterate-the-digital-knitting-machine.

Kniterate. "Knitting machines made for everyone," accessed October 29, 2018. https://www.kniterate.com/about.

Kniterate, "Timeline Update IV, Software Release and Knitting in London," published December 20, 2018, https://www.kniterate.com/2018/12/20/timeline-update-iv-software-release-and-knitting-in-london.

"Knitout" (Github code repository), last updated March 8, 2018. https://github.com/textiles-lab/Knitout.

"knitout-backend-swg" (Github code repository), last updated April 21, 2019. https://github.com/textiles-lab/knitout-backend-swg.

"Knitout Live Visualizer" (Github code repository), last updated April 23, 2019, https://github.com/textiles-lab/knitout-live-visualizer.

KnitYak. "About KnitYak," KnitYak, accessed March 8, 2019, https://knityak.com/pages/about-knityak.

KnitYak. "KnitYak: Custom mathematical knit scarves," Kickstarter, accessed March 8, 2019, https://www.kickstarter.com/projects/fbz/knityak-custom-mathematical-knit-scarves/description.

Kurbak, Ebru, and Yavuz, Mahir M. "News Knitter," last updated December 28, 2009, http://casualdata.com/newsknitter.

Kurbak, Ebru, and Yavuz, Mahir M. "News Knitter." In ACM SIGGRAPH 2009 Art Gallery, p. 29. ACM, 2009.

Malin Otmani, "Knitting and weaving artificial muscles," Nordic Life Science News, published January 26, 2017, https://nordiclifescience.org/knitting-weaving-artificial-muscles.

Maziz, Ali, Alessandro Concas, Alexandre Khaldi, Jonas Stålhand, Nils-Krister Persson, and Edwin WH Jager. "Knitting and weaving artificial muscles." Science advances 3, no. 1 (2017): e1600327.

McCann, James, Albaugh, Lea, Narayanan, Vidya, Grow, April, Matusik, Wojciech, Mankoff, Jennifer, and Hodgins, Jessica. "A compiler for 3D machine knitting." ACM Transactions on Graphics (TOG) 35, no. 4 (2016): 49.

Ministry of Supply. "Introducing Our 3D Print-Knit Shop," Ministry of Supply blog, accessed March 8, 2019, https://ministryofsupply.com/blogs/tested/introducing-our-3d-print-knit-shop.

Narayanan, Vidya, Albaugh, Lea, Hodgins, Jessica, Coros, Stelian and McCann, James. "Automatic machine knitting of 3D meshes." ACM Transactions on Graphics (TOG) 37, no. 3 (2018): 35.

Press, Mike. "Handmade Futures: The emerging role of craft knowledge in our digital culture." *NeoCraft: Modernity and the Crafts* (2007): 249-266.

Robbins, Freddie. “About,” accessed March 20, 2019, http://www.freddierobins.com/about.php.

Robbins, Freddie. “The Perfect,” published May 2, 2007. http://www.freddierobins.com/blog/the-perfect.

sameeragunarathne (username). “How do Shima Seiki Machines work?” (comment in forum), published May 25, 2015. https://github.com/fossasia/2018.fossasia.org/issues/1.

Shima Seiki. “SDS-ONE APEX3 Flat Knitting,” accessed October 29, 2018. http://www.shimaseiki.com/product/design/sdsone_apex/flat.

Shima Seiki. “What ‘Users’ Site’ can provide?,” accessed May 12, 2019. https://www.shimaseiki.com/user/kiyaku/index.php?cas=user.

“Shima Color Code,” The Hong Kong Polytechnic University, accessed October 29, 2018. http://158.132.122.156/knit/shima_color_code.htm.

Siren Elise Wilhelmsen. “365 Knitting Clock,” created 2010. http://www.sirenelisewilhelmsen.com/#365knittingclock.

Sayer, Kate, Jacquie Wilson, and Simon Challis. “Seamless knitwear-The design skills gap.” *The Design Journal* 9, no. 2 (2006): 39-51. 44

Soft Byte Ltd. “DesignaKnit Cable Links,” accessed October 29, 2018. https://www.softbyte.co.uk/cablelinks.htm.

Soft Byte Ltd. “DesignaKnit 8,” accessed October 29, 2018. https://www.softbyte.co.uk/designaknit.htm.

Salomone, Andrew. “Works,” accessed March 10, 2019, http://andrewsalomone.com/blog/works.

Salomone, Andrew. “Machine Knit Identity-Preserving Balaclava,” published December 30, 2010, http://andrewsalomone.com/blog/2010/12/30/machine-knit-identity-preserving-balaclava.

Takada, Kazunori, and Emi Urabe. “These Hi-Tech Knitting Machines Will Soon Be Making Car Parts.” *Bloomberg* online. Published October 2, 2017. https://www.japantimes.co.jp/news/2017/10/02/business/corporate-business/shima-seiki-wakayama-firm-built-knitting-empire-sets-sights-car-parts-manufacturing.

Taylor, Jane. “The technical designer: a new craft approach for creating seamless knitwear." PhD diss., Nottingham Trent University, 2015. http://irep.ntu.ac.uk/id/eprint/28318/1/Jane.Taylor2016excl.3rdpartymaterial.pdf.

Taylor, Jane, and Katherine Townsend. "Reprogramming the hand: Bridging the craft skills gap in 3D/digital fashion knitwear design." *Craft Research* 5, no. 2 (2014): 155-174.

"The Carnegie Mellon Textiles Lab," The Carnegie Mellon Textiles Lab, accessed October 28, 2018. https://textiles-lab.github.io.

The Girl and the Machine. "3D knitting on demand: revolution in clothing," One Planet Crowd, accessed March 8, 2019, https://www.oneplanet-crowd.com/en/project/171844/description.

The Girl and the Machine. "The Girl and the Machine - 3D Printed Knitwear," The Girl and the Machine, accessed March 8, 2019, http://www.the-girlandthemachine.com/en.

The Girl and the Machine. "The Girl and the Machine @ Mastery," The Girl and the Machine, published May 4, 2018, http://www.thegirlandthemachine.com/pers/the-girl-and-the-machine-mastery-the-dutch-milano/index.html.

Thomasson, Emma, "Adidas takes the sweat out of sweater shopping with in-store machine," Reuters, published March 20, 2017, https://www.reuters.com/article/us-adidas-manufacturing-idUSKBN16R1TO.

Treasure, Tom, Johanna JM Takkenberg, Tal Golesworthy, Filip Rega, Mario Petrou, Ulrich Rosendahl, Raad Mohiaddin, Michael Rubens, Warren Thornton, Belinda Lees, and John Pepper. "Personalised external aortic root support (PEARS) in Marfan syndrome: analysis of 1–9 year outcomes by intention-to-treat in a cohort of the first 30 consecutive patients to receive a novel tissue and valve-conserving procedure, compared with the published results of aortic root replacement." Heart 100, no. 12 (2014): 969-975.

Tucker, Emma. "3D Knitted Furniture Arrives at IKEA." Published December 12, 2016. https://www.dezeen.com/2016/12/12/ikea-3d-knitted-arm-chair-ps-2017-collection-design-sarah-fager.

Underwood, Jenny. "The design of 3D shape knitted preforms." PhD diss., RMIT, 2009. http://researchbank.rmit.edu.au/view/rmit:6130/Underwood.pdf.

Uniqlo. "A New Dimension in Knitwear: 3D Knit," accessed March 8, 2019, https://www.uniqlo.com/uk/en/pages/knitwear/3d-knit.

Unmade. “Home,” Unmade, accessed March 20, 2019, https://www.unmade.com/what-we-do.

Unmade. “Factory OMS,” accessed March 20, 2019, https://www.unmade.com/how-it-works/factory-oms.

“What is AYAB,” AYAB, accessed October 29, 2018. http://ayab-knitting.com/features.